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INFORMATION FLOW PLAN  
(GEMINI RENDEZVOUS OPERATION)  
Contract Number NAS 9-366  
(Preliminary Issue)

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WDL Technical Report E114-2

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(Preliminary Issue)

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Submitted to the  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
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## FOREWORD

This report is submitted to NASA Manned Spacecraft Center, Houston, Texas, under Contract NASA 9-366 on the "Design and Development Study for Manned Space Flight Operations Control and Support" (Gemini/Apollo GOSS Design Study). In particular, this report is submitted in accordance with paragraphs 3a (1) and (2) and 4a, Gemini Operational Procedures, Requirements Information Flow, Plan Information Flow, (Preliminary), of the Preliminary Statement of Work, MSC62-12, dated 24 April 1962.

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## INTRODUCTION

This interim report presents concepts of operation, information flow requirements and planning for Gemini rendezvous missions. This report is divided into six sections, entitled as follows:

- Section 1 — Mission Objectives and Description
- Section 2 — System Plan
- Section 3 — Required Information
- Section 4 — Accommodation of Requirements
- Section 5 — Information Flow Plan
- Section 6 — Manning Concept.

Section 1 begins with a general discussion of the mission objectives, and next delineates mission goals, and concludes with a description of the mission phases.

Section 2 presents the system plan and identifies general guidelines for operational and support ground rules, the required functions expected from this plan, and discussion of system segments.

Section 3 indicates the information required for this program based upon action and decision sequences and information sinks, and identifies the constraints placed on information flow.

Section 4 covers the accommodation of requirements by analyzing sources, display requirements, operations and procedures, data handling and, finally, data processing as each influences the system design.

Section 5 presents an information flow plan for Gemini flight missions.

Section 6, which concludes this report, discusses aspects of the manning concept and presents certain tentative recommendations.

It is intended that future revisions will be integrated into the basic report as the study analysis progresses. These revisions will also incorporate the results of pertinent technical discussions between Philco WDL, NASA-FOD and other participating groups.

## SECTION 1

### MISSION OBJECTIVES AND DESCRIPTION

#### 1.1 GENERAL

Section 1 discusses mission goals and description that have been discussed verbally with representatives of NASA-FOD and others, and as has been presented in the preliminary Statement of Work and other documents published concerning the Gemini rendezvousing program. The goals and description presented herein are not to be construed as presenting final determinations but, instead, represent what appears at the moment to be germane to the subject. Subsequent revisions of this report will phase out those goals and missions which prove to be inadequate and will phase in those which further study validates as pertinent to the Gemini rendezvousing program.

## 1.2 MISSION GOALS

As the Gemini Program has progressed in time, a number of specific program objectives, or mission goals, have been put forth by the Gemini Project Office and the NASA Flight Operation Division in Gemini documents. The list that follows summarizes these goals which have appeared in Gemini documents.

### 1.2.1 Engineering

- a. Demonstrate the capability of rendezvous between two earth orbiting vehicles, one of which is manned
- b. Develop flight and ground operational techniques for flights of long duration
- c. Establish orbital rendezvous techniques
- d. Establish dispersion and landing techniques for controlled land landings
- e. Develop rendezvous technology as may be applicable to Project Apollo
- f. Evaluate equipment for Project Apollo.

### 1.2.2 Scientific

- a. Physiological and psychological evaluation of the two crewmen for extended periods in spacecraft environment
- b. Evaluation of the performance capabilities of the crew while being subjected to extended periods in a space environment.

### 1.2.3 Political

- a. Establish the U. S. A. as the first nation to achieve manned lunar landing and return (alive).
- b. Conduct all missions only for scientific research and exploration.

### 1.2.4 Military

- a. None

### 1.3 MISSION DESCRIPTION

#### 1.3.1 General

The following subsection, 1.3.2, Mission Phases serves to describe any Project Gemini Mission, i. e., the "18-orbit unmanned" through the "2-day rendezvous." The phases are purposefully sufficiently general to describe any mission. There are, however, certain portions of this report (e. g., communication system loading, display requirements, etc.) which are based on a particular mission profile during which some maximum or extreme situation is exhibited and GOSS response to this extreme or maximum is analyzed. In this report, the particular mission used to illustrate extremes is always the 2-day rendezvous inasmuch as this mission contains the same (and more) phases and subphases as any of the other missions. . . . (and our contract only covers rendezvous missions).

Several profiles are being considered currently for the two-day rendezvous missions. Because of the required concurrency of analysis efforts, both the mission analysis being performed by the NASA-FOD and the information flow requirements being developed by Philco WDL are proceeding in parallel. It is necessary, therefore, to select from the alternatives available a profile (or part of a profile) on which the development of information requirements can be predicated. Since the objectives of the study and development of information flow requirements do not include the specification or selection of a mission profile, a selection will be made only when certain aspects of the profile influence the design and operation of the GOSS. Selection is based on one principal item, the profile which it is believed will impose the most serious constraints on GOSS.

In this report it has been necessary to specify the launch order of the two rendezvousing vehicles (Gemini and Agena). There have been a number of arguments proposed by operations personnel for the NASA-FOD for launching the Titan/Gemini first and also for launching the Atlas/Agena first. It has been assumed in this report that the Titan/Gemini



will be launched first because the more serious constraints seem to be imposed by this launch order. The reasons which make explicit the constraints in GOSS that have been stated by the NASA-FOD personnel for this launch order are as follows:

- a. The current uncertainty regarding the predictability of the Titan second-stage cut-off velocity and the Gemini weight suggests that the Gemini guidance and OAMS engines (along with on-board fuel) may be used to attain the desired orbit. The fuel required to perform the insertion places serious limits on the subsequent maneuvering capability of the Gemini spacecraft. Orbit plane changes, and subsequent major maneuvers, of necessity, must rely on the remaining capability of the Agena engines. Hence, if the final rendezvous orbit is to be in view of the existing tracking station network, and if the launch window is to be kept sufficiently large, then the Gemini must be launched first at a fixed azimuth. (A launch window is "sufficiently large" if it allows a high probability of primary mission success, even with short holds during launch of the Agena.)
- b. The first system to be launched can be injected into any desired orbit inclination (within range safety limits). The selection of orbit inclination prior to launch allows the size of the contingency recovery area to be limited to a size that can be well-patrolled. Thus, maximum assurance of contingency recovery is provided if the Gemini is launched first.
- c. The Titan/Gemini configuration, being more complex and required to support human life, has a more sensitive, more difficult-to-complete countdown. Completion of the Gemini countdown marks the completion of a greater portion of the total mission than is marked by the completion of the Atlas/Agena countdown. The launching of the Gemini is a greater milestone than the launching of the Atlas/Agena and should be completed first. No Gemini launching will be "wasted," regardless of the status of the Atlas/Agena, if an alternate (to the rendezvous) mission is planned prior to each rendezvous mission countdown. Man's time-in-space is far too short to justify a feeling of waste if the Atlas/Agena fails to rendezvous when an alternate mission could have been undertaken.
- d. If the Atlas/Agena configuration were to be launched first, the Gemini orbit inclination could be unknown (and, in turn, the contingency recovery area would remain unknown until its time of launch) unless the launch window were made very narrow, a condition unlikely to be satisfactory in light of the uncertainties of the Gemini countdown.

In the development of the information flow requirements and the design of the IMCC, it may become evident that certain profiles may impose severe constraints on the GOSS. Under these circumstances, future issues of this report will present descriptions of the constraints imposed on the GOSS. Also, recommendations will be made, when alternate profiles are available, as to which profile minimizes the constraints on the GOSS.

### 1.3.2 Mission Phases

Mission phases serve a threefold purpose in this report. They are a convenient and useful way in which to break a flight plan or mission profile into tractable pieces capable of being analyzed; they serve as the starting point from which one proceeds to develop action sequences, i. e., mission phases are the "least detailed" set of action sequences; they serve as a media for introducing problem areas in the study plan, as is subsequently illustrated.

Discussing first the role of mission phases as subdivisions of a mission profile, one immediately encounters the "two-vehicle" problem -- should rendezvous missions have different phases than single-vehicle orbital missions? This problem is resolved by defining an invariate set of phases for Project Gemini. For a rendezvous mission, each booster/spacecraft pair is assigned the same set of phases and one simply combines two vehicle-assigned phases to define the overall phase, e. g., checkout-launch, orbit-orbit, orbit-reentry. The convention used is to place the Gemini/Titan phase before the Atlas/Agena phase.

The mission phases are presented in chronological order so that a complete list of phases reflects a nominal, planned mission profile. In the event of the occurrence of a contingency (sufficiently severe as to cause an abort), the list of mission phases is still valid; however, sections of it are deleted or circumvented. For example, an abort situation arising during the Agena/Gemini rendezvous could require immediate termination of Gemini orbit phases and passage into its reentry phase without "passing through" the phases or sub-phases listed, nominally, between the orbit and reentry phases. Hence, one criterion used to validate a list of mission phases is the capability to delete entire segments of the list of phases without affecting the significance of the remaining members of the list -- insofar as the remaining members reflect a possible, emergency mission profile.

The mission phases are listed below, and then discussed in the paragraphs immediately following:

- a. Checkout Phase
- b. Launch Phase
- c. Powered-Flight Phase
- d. Orbital Phase
- e. Reentry Phase
- f. Recovery Phase

1.3.2.1 Checkout Phase. The checkout phase is defined to commence at approximately  $T_0$  -60 days or at such time as one Titan II, one Gemini spacecraft, one Atlas E, and one Agena D are all present at Cape Canaveral (the latter two being required only in the case of a rendezvous mission) and assigned to a Gemini mission. For the purposes of defining a "present" or "not-present" situation, the launch vehicles are present when installed on their respective launch pads and the spacecrafts are present when housed, for checkout, in the Gemini-equivalent of the Project Mercury Hangar "S."

Before continuing with the phase description, one must note that the checkout phase, when used in a rendezvous mission profile, introduces a new and challenging problem: countdown synchronization. Preceding a rendezvous flight, the prelaunch checkout and preparation of the Titan/Gemini systems cannot proceed independently of checkout and preparation of the Atlas/Agena systems; both systems must approach readiness and  $T_0$  at nearly equal rates. Holds in the prelaunch countdown of one system are very likely to precipitate holds in the countdown of the other system. The Flight Director or his pre-launch representative must be aware of and assisting in coordinating interaction countdown holds between systems.

The solution to this synchronization problem will be developed in subsequent sections of this report. Initial consideration regarding a solution, however, are presented below.

A possible arrangement for controlling holds appears in Figure 1.3.2-1. This would be appropriate during the period  $T_0$ -60 days to about  $T_0$ -7 days. Thereafter, hold decisions are tempered by inputs from other members of the IMCC mission control organization (e.g., weather influences sensed and conveyed to the Flight Director and the Operations Director by the Recovery Control Operations Coordinator).

Returning to the phase description the checkout phase includes the assembly operations of bolting each spacecraft to its respective launch vehicle. It also includes the network checkouts by system simulation. The checkout phase is defined to end, however, whenever the countdown, with intent to launch, is initiated (at, for example,  $T_0$ -24 hours).

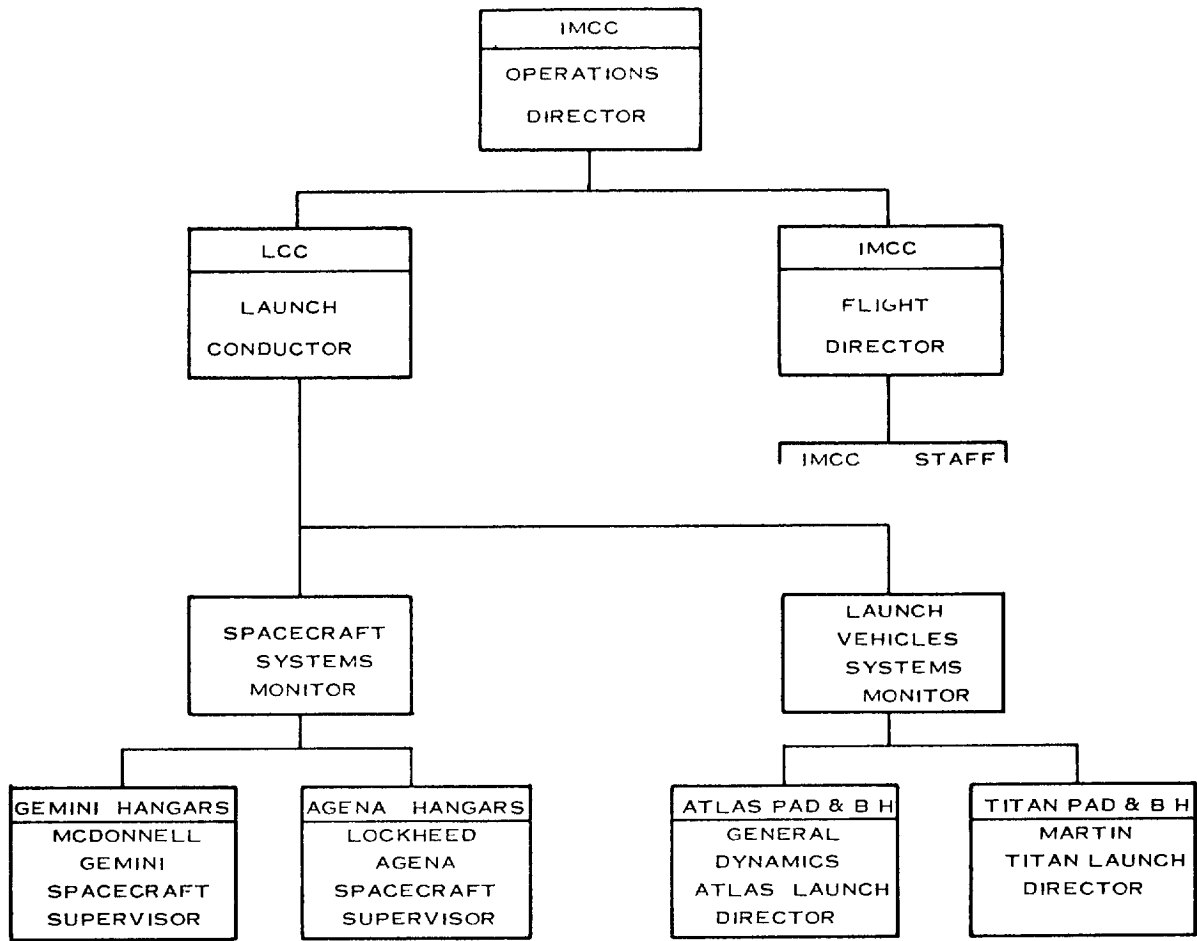
1.3.2.2 Launch Phase. The launch phase commences whenever the launch (as opposed to checkout) countdown is initiated. During this phase, the countdown synchronization problem becomes a severe one inasmuch as synchronization by hours may be required.

The termination of this phase is at  $T_0$ , the time at which the launch vehicle hold-down clamps are released. This time,  $T_0$ , is to be used as the primary reference "tick" mark in the mission profile. Regardless of which vehicle is launched first, their respective time-histories are coordinated by locating the two launch times in the action sequences and aligning these tick marks appropriately (i.e., one mark moved ahead, in time, of the other mark to indicate non-simultaneous launches).

1.3.2.3 Powered-Flight Phase. The powered-flight phase commences at the previously-defined time,  $T_0$ . This phase is best described by enumerating briefly some of the events which occur during this phase. (The times are approximate.)

Events assigned to Titan/Gemini:

- a.  $T_0$ : hold-down clamps released
- b.  $T_0 + 30$  sec: pitchover
- c.  $T_0 + 55$  sec: self-eject mode terminated, capsule  
reentry mode initiated



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Figure 1.3.2-1 Checkout Organization

- d.  $T_o + 60$  sec: max. "Q"
- e.  $T_o + 180$  sec: 1st stage burnout
- f.  $T_o + 181$  sec: 1st stage jettison
- g.  $T_o + 185$  sec: 2nd stage ignition
- h.  $T_o + 330$  sec: 2nd stage burnout
- i. Sense "0.2g" Spacecraft separation  
posigrade burn (OAMS engines)
- j. Separation + 1 sec: Rate-damping mode for 5 sec.
- k. Separation + 6 sec: Spacecraft turn-around (orientation mode)
- l.  $T_o + 340$  sec: Orbit/rendezvous attitude attained  
(0° roll, 0° pitch, 0° yaw) (orbit, orbit modes).

Events assigned to Atlas/Agena:

- a.  $T_o$ : hold-down clamps released
- b.  $T_o + 30$  sec: pitchover
- c.  $T_o + 60$  sec: max. "Q"
- d.  $T_o + 135$  sec: BECO
- e.  $T_o + 303$  sec: SECO, Agena spacecraft separation,  
Agena engines ignition.

The powered-flight phase is defined to terminate with the cut-off of the orbit insertion engines.

The powered-flight phase is described in such detail to reveal another criterion for "designing" mission phases or partitioning the mission profile. It is obvious that, in terms of duration, the powered-flight phase is disproportionately shorter than, for example, the checkout phase. It will be shown subsequently, however, that the decision-point density per unit time is within an order of magnitude of the density of any other phase. The mission profile is intentionally partitioned to equalize the information requirements (information being an input to a decision-point) among the mission phases. This leveling or equalization becomes apparent as the action sequences, within each phase are developed.

1.3.2.4 Orbital Phase. The cutoff of the orbit insertion engines marks the beginning of the orbital phase. This phase is terminated by the ignition of retrograde engines with intent to reenter.

The orbital phase is the only phase which one can examine to identify a particular mission profile (i.e., orbital rendezvous, etc.). The duration of this phase partially identifies the profile (e.g., 14-day orbital, 2-day rendezvous) and the subphases included within this phase complete the identification. Tentatively, the following subphases are to be used:

- a. Plane change
- b. Ellipticity adjust
- c. Rendezvous preparation
- d. Rendezvous
- e. Docking
- f. Separation "undocking".

These subphases appear to satisfy the "equal information" requirement criterion (paragraph 1.3.2.3) as though they were (themselves) phases. They fail, however, to satisfy the "circumvention" criterion (paragraph 1.3.2) and thus are classified as subphases.

The subphases are briefly discussed below:

- a. Plane Change. The plane change subphase commences with the first spacecraft attitude change (away from  $0^\circ, 0^\circ, 0^\circ$ ) with the intent to change orbit planes. When the attitudes are all correct, the Agena or Gemini OAMS engines are ignited and burn until the appropriate plane change velocity has been acquired. The spacecraft attitude is then re-adjusted to  $0^\circ, 0^\circ, 0^\circ$  with respect to the "new" orbit. When the attitude adjustment is complete, the spacecraft returns to orbit mode and the plane change subphase is complete.
- b. Ellipticity Adjust. The ellipticity adjust subphase is initiated by a pitch adjustment with intent to change orbits. Again, as with the plane change maneuver, the retrograde or posigrade engines are ignited and burn until the required ellipticity is attained. Return to orbit mode and  $0^\circ, 0^\circ, 0^\circ$  attitude terminates this subphase.



- c. Rendezvous Preparation. Rendezvous preparation commences when the Gemini radar first acquires the Agena with the intent to complete a rendezvous maneuver and subsequent docking. All maneuvering to bring the spacecrafts within optical tracking distance is contained in this subphase. Rendezvous preparation is complete when visual contact, Gemini-to-Agena, is established.
- d. Rendezvous. Rendezvous commences when visual, Gemini-to-Agena contact is established, and after maneuvering of the spacecraft takes place, terminates when the separation of the spacecraft is less than 10 feet and the closing velocity is less than one foot per second.
- e. Docking. When the relative spacecraft positions have closed to within 10 feet and the closing velocity is less than one foot per second, the docking subphase commences. The Gemini extends its docking mechanism and "grapples" the Agena. When the crafts are in physical contact and "locked together" both mechanically and electrically, the docking subphase is complete.
- f. Separation. Separation is regarded as the exact inverse of docking

1.3.2.5 Reentry Phase. The reentry phase is divided into three subphases. These subphases fail to satisfy the "equal information requirement" criterion whereas they do satisfy the "circumvention" criterion (i. e., these subphases are grouped as such for exactly opposite reasons than were the orbital subphases). The three subphases are:

1. Retrograde
2. Reentry
3. Descent

- a. Retrograde. The ignition of the retrograde engines with the intent to reenter terminates the orbital phase and initiates the retrograde subphase and the reentry phase. Final burnout of the retrograde engines marks the termination of the retrograde subphase.
- b. Reentry. The reentry subphase begins at the time of final burnout of the retrograde engines and ends when the first landing aid is deployed (e. g., drogue chute.) During this subphase, "0.05g" is sensed and the retro package is jettisoned. In addition, the  $10^{\circ}$ /sec roll rate is initiated.

- c. Descent. The deployment of the first landing aid initiates the descent subphase. During this subphase, the drogue chute(s) are deployed and are followed by deployment of the paraglider. The cabin is opened to outside atmosphere and the locating beacons are energized. This subphase ends with land (or water) contact.

1.3.2.6 Recovery Phase. The last phase to be described is the recovery phase. (Note that this phase is not necessarily the last phase of any mission profile when the profile is considered on a "per vehicle" basis. The Agena spacecraft may very likely never be recovered. In fact, the Agena may never purposely be commanded into the reentry phase. The list of mission phases is still valid, however, inasmuch as it was designed with consideration of the circumvention or deletion of phases in certain instances.) This phase commences with the contact, by the spacecraft, of the Earth (land or water). Sometime during the early moments of this phase, all locating aids are energized and/or deployed (e.g. SARAH, ULTRASARAH, dye markers, flares, etc.). This phase is terminated when the spacecraft (and/or its crew) is released from recovery operations control.

## SECTION 2 SYSTEM PLAN

### 2.1 OPERATIONAL AND SUPPORT GROUND RULES

#### 2.1.1 General

The purpose of this section of the report is to present the basic guidelines as set forth by the NASA for the design of GOSS (as it should support the Gemini Project). As the development of the project progresses, such a record can serve as a basis from which guiding ground rules can be extended or changed, and will serve as a monitoring list to minimize potential conflicts. The very brief list that is presented at this time will be expanded in the next report to provide a more exhaustive picture of the guiding technical policy.

#### 2.1.2 General Guidelines

- a. GOSS must adapt itself to missions, i. e. , the GOSS must exert a minimum constraint on the planning for manned spacecraft missions. Development of specifications for new missions must include requirements for GOSS adaptation.
- b. GOSS should be designed so that, if GOSS capabilities were to become degraded to a limited extent, the reliability of any mission (specifically Gemini) supported by GOSS would not be further degraded.
- c. GOSS response to all contingencies should have been pre-planned to the maximum extent.
- d. Where similar functions are to be performed at separate locations, similar equipment using similar operating procedures at each location should be provided.
- e. GOSS contact with the spacecrafts should be:
  1. By voice . . . . . Twice per orbit
  2. By command link . . . . . Once per orbit
  3. By TLM dump . . . . . Once per orbit
- f. Every discrete "command" from GOSS to a spacecraft should be verified.

- g. GOSS must be designed so as to function at peak efficiency during contingencies.
- h. Control of the AGENA shall always be by radio-frequency links:
  - 1. By GOSS
    - Attitude
    - Vernier thrusters
    - Main Engine
  - 2. By GEMINI
    - Attitude
    - Main engine

Note: Gemini provides control whenever this is physically possible.

## 2.2 REQUIRED FUNCTIONS

Certain phases of flight have alternate modes of operation which imply distinct command relationships between the GOSS and the spacecraft crew. The paragraphs that follow identify the principal phases or sub-phases, and the responsibilities of the GOSS in these portions of flight, starting with powered flight.

### 2.2.1 Powered Flight Phases

The responsibilities in the GOSS, during powered flight, remain the same as during the launch phase of the mission described in paragraph 1.3.2. There is, however, one notable addition to the LCC structure during powered flight; the Range Safety Officer (RSO). During the powered flight of unmanned vehicles, the RSO has the ultimate responsibility to cut off the engine and destroy the launch vehicle in the event of potential hazard to life. The capability of the RSO during the powered flight of the Titan/Gemini is much the same except that he is expected to inform the Gemini crew and the Flight Director as to the time abort will be required so that the crew has an opportunity to eject.

Whenever range safety limits are about to be exceeded, the RSO informs the FD of the situation and places an upper limit on the immediacy of any action to be taken by the crew or the FD. The FD is obliged to meet the RSO's time constraint. If no action is taken within the prescribed time limit, full responsibility for range safety and full authority to destroy the booster rests with the RSO.

### 2.2.2 Rendezvous Preparation Subphase

There are a variety of ways in which each subphase of the orbital phase of the mission profile can be handled, depending upon the overall mission objectives and contingencies which may occur. A delay at launching, erroneous guidance at launch, failure of the booster to perform properly, erroneous insertion into orbit, failure of ground tracking equipment, etc., will result in different modes of operation being selected.

at each point at which a decision must be made. Considerations of the various modes of operation, which may be used, are presented in the following subsections of this report.

The identification of major sequential events and consideration of possible variations in operational mode make possible detailed discussion of the functional responsibilities of major GOSS elements. This is especially so, in view of the large number of possibilities for the GOSS functional responsibility resulting from relatively few variations in the mode of operation. Since many of these will be ruled out for other reasons, extreme detail is not attempted here. Rather, the major items of functional responsibility are indicated in the subsections 2.2.2.

#### 2.2.2.1 Modes of Operation.

- a. Normal Mode. In the normal mode of operation, the Gemini crew will control all maneuvers of the Gemini spacecraft during this subphase. The control of the Agena will be the responsibility of the GOSS.
- b. Secondary Mode. In the secondary mode, the Gemini crew will still originate the commands to the OAMS but the information regarding attitude at time of thrust, time of thrust application and magnitude of thrust will be determined by GOSS. The Agena will still be controlled by the GOSS in this mode of operation.
- c. Command Mode. In the command mode, both the Gemini and Agena will be ground commanded for orbital maneuvers.

2.2.2.2 GOSS Responsibilities. It will be necessary for the IMCC to obtain and maintain an accurate ephemeris of both vehicles. The thrust programs to circularize an elliptical orbit, to transfer between two circular or elliptical orbits, or to perform an orbit plane change will be determined by the IMCC. The IMCC will delegate the command transmission responsibility to an "A" ground station (having command capability) as required by the orbital parameters and the ground coverage. The decision to terminate the mission or proceed with the planned phases will be the responsibility of both the IMCC and the vehicle crew with final responsibility vested in the astronauts. Both the IMCC and crew can independently make the abort decision, but the crew will normally

initiate the required abort actions as indicated in the retro and reentry phases of flight to be described in subsequent sections.

During the planning of gross maneuvers, the IMCC has the additional responsibility to determine the tradeoffs between thrust maneuvers in the Agena and in the Gemini. If there are alternate thrust programs available using both vehicles to achieve a desired end condition, the IMCC will be responsible for selecting the optimum relative maneuver for each vehicle.

### 2.2.3 Rendezvous Subphase

2.2.3.1 Modes of Operation. In the normal mode of operation, the spacecraft crew will have complete control over the rendezvous subphase of flight. The Gemini spacecraft will generate the required information and the crew will initiate the required actions. In the secondary mode, the crew will have complete and sole control as before, but the GOSS will provide the required information for Gemini maneuvers. One careful distinction must be made. In the normal mode, the GOSS will provide the crew with Agena status information but the Gemini crew will command the Agena, as required. In the secondary mode, the ground will not only supply Agena status information to the crew but will also command the Agena, as required.

It does not appear necessary to have a distinct command mode in this phase of flight. For example, if the Gemini crew cannot extend the docking mechanism, there may be no desire to complete the rendezvous, so there would be no requirement for the ground to be able to command the final docking actions.

2.2.3.2 GOSS Responsibilities. In this phase, there are two important aspects of GOSS responsibility. First, the IMCC must carefully evaluate the status of Agena systems and the possible dangers to the Gemini crew if docking is attempted. The decision to abort or not to dock is made by the crew. A secondary responsibility will probably be assigned to the IMCC. The second important responsibility is that of control transfer.

At some point in the initial period of rendezvous, the IMCC must transfer control of the Agena to the Gemini spacecraft. This transfer time will be determined by the IMCC based on system status information and vehicle position. The transfer time will be coordinated with the Gemini crew and effected as required.

In this subphase of flight, the decision to abort or not to dock will be closely allied with the collision avoidance problem. If collision is likely, the IMCC will back up the Gemini crew in determining the optimum collision avoidance maneuver for each vehicle.

#### 2.2.4 Docking Subphase

This phase of flight is basically unimodal. All actions are manually initiated by the crew, including Agena commands. The only major role exercised by the GOSS during this phase of flight is that of monitoring the telemetered data from the Agena and transmitting status information to the Gemini crew. The decision to abort or not to dock will be made by the IMCC only if Agena systems information indicates hazard or there is evidence of incapacity of the Gemini crew.

#### 2.2.5 Orbital Phase-Coupled Maneuvers

The coupled maneuver begins with stabilization of the vehicle pair to obviate the rotation resulting from the coupling operation. This phase will include experimentation to get the "feel" of the new controls, pre-planned maneuvers with the coupled vehicles, and possible use of the Agena thrust capability to achieve an orbit more favorable for retro-sequence. It will end with a return to a stable vehicle position prior to separation of the vehicles in the next phase. It is expected that this portion of the rendezvous sequence will be subject to considerable variation depending on the mission modes chosen but operational support requirements resulting from these various modes will probably not vary extensively.

##### 2.2.5.1 Modes of Operation. The normal mode of operation will be



manual under the control of the Gemini crew. The control of the Agena system will be RF controls operated by the crew. The Agena engine and the OAMS will be exercised by the crew in this mode of operation. There will also be a limited command mode. The GOSS will have command capability over the restarts, vernier thrusting, and the attitude control of the Agena. Ground command is strictly an emergency operation in this phase.

2.2.5.2 GOSS Responsibilities. The responsibility of the IMCC and ground stations is the same as stated for the predocking phase. That is, the responsibility over systems status in the Agena and mission abort does not change. The IMCC will be responsible for recommending modification to planned maneuvers for the combined vehicle based on energy management considerations, and the status and location of recovery forces. Specific maneuvers and experimentation will have been established as part of the mission plan.

#### 2.2.6 Separation Subphase

2.2.6.1 Modes of Operation. The normal mode of operation is the same as docking. In a secondary mode, the GOSS will be able to effect separation by command.

2.2.6.2 GOSS Responsibilities. The responsibilities of the GOSS will be the same as for docking and combined vehicle maneuvers. It has been assumed that the Agena will not be controlled once separation occurs, until after the Gemini has landed. At this time, the IMCC may choose to experiment with the Agena by commanding various orbital maneuvers or may choose to initiate an engine restart and destructive reentry.

#### 2.2.7 Retro Subphase

2.2.7.1 Principal Actions Involved in the Retro Subphase. There are four basic actions involved in the retro subphase: (1) spacecraft separation, (2) equipment section separation, (3) attitude adjustment

of the Gemini, and (4) retrofire. Each of these will be discussed briefly to identify clearly these actions:

- a. Spacecraft Separation. When the docking mechanism releases and the electrical connector separates, the Gemini spacecraft must be physically separated from the Agena. This separation will be achieved by exercising the OAMS of the Gemini.
- b. Equipment Section Jettison. After the separation of the two vehicles is complete, the equipment section in the Titan/Gemini adapter will be jettisoned by the crew. The OAMS is located in this portion of the adapter and hence will no longer be available for Gemini maneuvers. Also, the electronics and equipment required for transmitting stored or recorded information (in the Gemini) are located in the portion of the adapter which will be jettisoned. Therefore, in addition to losing the OAMS in the equipment section jettison, the ability to transmit recorded data in the Gemini will also be lost. The jettison will be effected by an explosive charge between the equipment section and retro section of the adapter unit.
- c. Attitude Control of the Gemini. Prior to initiating retrofire, it will be necessary to adjust the attitude of the Gemini spacecraft. Since the OAMS will have been jettisoned, attitude control will be exercised by the reaction control system (RCS). There are actually two independent RCSs in the small end of the Gemini spacecraft. Only one system will be used for the attitude control prior to retrofire.
- d. Retrofire. When the Gemini is in the proper attitude, the retros, located in the remaining portion of the adapter, will be fired. The termination of the retrofiring ends the retro-sequence. It is not expected that any actions will involve the Agena during this phase of flight.

2.2.7.2 Modes of Operation. The normal mode of operation will be manual. The separation of the two vehicles, the jettison of the equipment section, the attitude control, and the retrofire will be manually initiated by the crew by direct control or initiation of a timing device. The crew will not depend on ground-supplied information to perform the actions. The secondary mode of operation will be manual as above but the actions will be based on information supplied by the GOSS over the voice link. The third basic mode, or command mode, of operation will be based on ground support completely. Bilevel commands may be sent by the GOSS to effect equipment section jettison, attitude control of the Gemini, and retrofire.

### 2.2.7.3 GOSS Responsibilities.

- a. Normal Mode. In the normal mode of operation in the retro-sequence, the attitude adjustment and retrofire will take place in view of an "A" ground station. Here "A" designates a remote site with the capability to receive telemetry and transmit commands in addition to the voice communication and tracking capability. The "A" ground station will be responsible for maintaining voice contact during attitude adjust and retrofire.

The station will have the capability to selectively monitor propellant controls, condition, and storage of the OAMS to provide verification of OAMS status in the event voice and digital communications cannot be maintained between the vehicle crew and the IMCC.

The station will also monitor the telemetry signal which indicates separation of the equipment section of the Titan/Gemini adapter. Since this is initiated by an explosive charge, there should be ample feedback to the crew that the jettison has occurred. Since it is assumed that the equipment section will be jettisoned just before retrofire, the event should be detectable in real time by the ground station.

The spacecraft attitude prior to retrofire will also be monitored by the ground station to provide immediate verification to the Gemini crew that attitude is satisfactory for retrofire. This verification will back up the on-board attitude/retrofire interlock. The station will also be responsible for monitoring the time of ignition of each of the four retro rockets to insure that all have fired properly. This information, obtained from telemetered data, will be fed back to the vehicle crew over the voice link as backup verification. The data on attitude and ignition of retro rockets, coupled with tracking data, will serve as backup information to facilitate computation of the predicted impact or landing point. The IMCC will be evaluating the Reaction Control System (RCS) and other systems for determining any desired deviations from the planned touchdown control maneuvers. The expected landing point and associated confidence levels will also be continually updated in this phase of flight by the IMCC. The IMCC will have the capacity to determine "go" conditions on the equipment section jettison and the retrofire as required by the crew or in support of the crew.

- b. Secondary Mode. In this mode of operation, all crew-initiated actions are based on ground-supplied information. This can be paraphrased by saying that the crew can perform all manual tasks but are information blind, or that they are acting simply as transducers in the control loops. In this mode, the IMCC will determine metered thrust requirements in the OAMS for Agena-Gemini separation, time of thrust application for

separation, time of equipment section jettison, required actions and times of actions in the RCS for attitude control during retrofire, and the time of retrofire. Depending on the final configuration of the spacecraft, these data will be transmitted to the vehicle crew on the voice link or the digital command link for display in the spacecraft or a combination of both. The ground station will act as backup to the IMCC for voice or digital transmissions but will not make the required data determinations independently of the IMCC. The information flow plan for this portion of the retrophase will be presented in subsequent reports.

- c. Command Mode. In this third mode of operation, the determinations discussed above will be transmitted to the spacecraft on the digital command link. The distinctions between real-time and stored-program commands for this phase of flight as well as the bilevel or multilevel nature of these commands will be detailed in subsequent issues of this report.

There will actually be as many modes of operation as there are permutations of automatic actions, crew initiated actions, ground initiated actions, and information exchanges. It is not useful, however, to detail more than the three that have been indicated. Mission rules, operating procedures, etc., will clearly spell out the mixture of operational modes which will generally be dictated by contingencies. Operations, under contingency situations, are to be of prime importance in planning and analyzing the GOSS performance requirements. Current examinations are centered around such contingencies as:

- (1) Disconnect of Agena and Gemini not possible by electrical means
- (2) RCS damage in docking
- (3) Paraglider section damage in docking
- (4) Premature separation of equipment section of adapter
- (5) No attitude feedback from RCS
- (6) No attitude feedback from OAMS
- (7) Failure of explosive charge to separate equipment section
- (8) Incomplete retrofire
- (9) Failure of on-board computer
- (10) Loss of telemetry and command verification
- (11) Failure of digital command system
- (12) Premature retrofire and/or short burn
- (13) Partial or complete failure of OAMS

- (14) Failure of receiving equipment at ground station
- (15) Loss of signal in command mode
- (16) Loss of digital communications between IMCC and ground station
- (17) Inertial Guidance System (IGS) transducer failure
- (18) Failure of ACME and horizon sensors
- (19) The entire retrophase executed out of ground station view
- (20) Loss of space-to-ground voice links
- (21) Incapacity of crew.

## 2.2.8 Re-Entry Subphase

### 2.2.8.1 Principal Actions Involved in the Reentry Phase

There are seven basic actions involved in the reentry phase of flight.

A brief discussion of each follows:

- a. Retrograde Package Jettison. After the retro rockets have been fired, the remaining portion of the Titan/Gemini adapter will be jettisoned. This portion of the adapter contains the retro rockets.
- b. Reentry Attitude Control. Once the retrograde package has been jettisoned, the attitude of the Gemini will have to be adjusted as is currently done in Project Mercury. This control of reentry attitude will be effected with one of the Reaction Control Systems in the small end of the Gemini. This RCS is capable of controlling the roll, pitch, and yaw of the Gemini.
- c. Reentry Roll Control. When the reentry attitude has been properly adjusted, it will be necessary to continually maneuver the Gemini to effect a stable reentry. It is assumed that a ten degree per second roll on the flight path will be required to keep the Gemini stable and to reduce local heating. This requirement is based on the planned angle of reentry and the offset center of gravity of the spacecraft. This roll control will be achieved by the RCS operation.
- d. Docking and Rendezvous Housing Jettison. The jettison of the docking equipment and rendezvous housing will take place below 80,000 feet altitude. The rendezvous radar, docking and antenna package, RCS, and the rendezvous package housing will all separate from the Gemini.
- e. Drogue Chute Deployment. The drogue chute can be deployed only after the docking and rendezvous housing has been jettisoned. The drogue is the first landing aid to be extended for initial capsule slowdown.
- f. Paraglider Deployment. The drogue chute extension will be followed by paraglider deployment. The paraglider will be deployed by two actions. The first is the release of the back end of the paraglider, and the second is the release of the front end.
- g. Paraglider Inflation. Following the paraglider release, the paraglider will be inflated.

2.2.8.2 Modes of Operation. It is assumed that this entire sequence, except reentry attitude adjust, will be automatic (will require no manual

action) in the normal or primary mode of operations. The positioning for reentry will be manual. In the secondary mode of operation, the spacecraft crew will manually jettison the retrograde package and position the vehicle for reentry. The roll control will be effected by the RCS in a mode analagous to the "fly-by-wire" operation in the Mercury capsule, and the jettison of the docking and recovery housing will be manually initiated. The deployment and inflation of the paraglider will still be automatic following the recovery housing jettison.

#### 2.2.8.3 GOSS Responsibilities During Reentry Subphase

- a. Normal Mode. In the normal mode of operation, the IMCC will play no direct role in this subphase of the Gemini flights. The IMCC will receive tracking data only during this phase since it is not expected that the reentry event sequence will necessarily occur over an "A" ground station. From the tracking data, the landing prediction information will be determined at the IMCC on a continual basis as data is received. The ground station over which this reentry subphase occurs will be responsible primarily for maintaining an active tracking operation and for maintaining the space-to-ground voice link. When the retro rockets have fired, the separation of the remaining adapter or retrograde package jettison will take place as an automatic sequence. The following attitude adjust with the RCS will be the only manual operation in this normal mode of operation. Once the attitude is proper for reentry, the roll program for stabilization will be automatic. Automatic jettisoning of the docking and recovery housing section is initiated by an altitude sensor. The deployment in two stages and subsequent inflation of the paraglider will also be automatic in sequence following the release and separation of the docking and recovery housing section.
- b. Secondary Mode. In this mode of operation, the functions of the IMCC do not differ from the primary mode. The spacecraft crew will manually jettison the retro package section of the adapter and manually position the spacecraft for reentry. The reentry roll program will also be exercised in a manual or a semi-automatic mode analagous to the "fly-by-wire" system in the Mercury capsule. Based on altitude indications, the crew will manually jettison the docking and recovery housing section of the Gemini. The deployment and inflation of the paraglider will then occur automatically.

Careful examination and analysis will be given to a large set of major contingencies including:

- a. Failure of retrograde package to separate
- b. Failure of #1 or #2 RCS
- c. Loss of attitude feedback information
- d. Short or long burning of retro rockets
- e. Failure of on-board computer
- f. IGS transducer failure
- g. Failure of ACME and horizon sensors
- h. Failure of docking and recovery housing section to jettison
- i. Premature jettison of docking and recovery housing section
- j. Failure of paraglider deployment mechanism
- k. Partial (or incomplete) inflation of paraglider.



## 2.2.9 Descent Subphase

2.2.9.1 Modes of Operation. There is only one mode of operation in the descent phase of flight. The astronauts will maneuver the spacecraft manually with the paraglider. The extension of skids will also be manual.

2.2.9.2 GOSS Responsibilities. The only GOSS responsibility in the descent subphase will deal with recovery operations. During descent, recovery units will maintain voice contact when possible and will track if possible. There is no requirement for ground support during descent other than the voice and tracking requirements.

## 2.2.10 Recovery Phase

2.2.10.1 Description of the Recovery Phase. The basic objectives of Project Gemini are to launch a two-man satellite vehicle into orbit and to investigate techniques for rendezvous and docking with a target vehicle while in orbit. The overriding consideration, however, is crew safety. Situations may occur which require unscheduled landing and recovery of the crew and, if possible, the spacecraft as well. Recovery capability must be established for pad aborts, in-flight aborts prior to orbital insertion, and for orbital aborts, in addition to normal landing at mission termination.

Recovery operations may be divided into two categories, orbital and suborbital. Orbital recovery capability from each orbit is considered necessary to handle emergency conditions associated with failure of onboard systems, crew medical requirements, or other emergency conditions. Planned orbital recovery locations for normal flight termination will not be sufficient to handle all contingencies. Suborbital recovery has two aspects, (1) pad abort and early flight abort (below 20,000 feet) and (2) recovery from suborbital flight (above 20,000 feet, but prior to orbital insertion). The various recovery situations are described separately in the following subsections.

- a. Recovery from Orbital Flight. The proposed recovery operational plan is based on the following assumptions:
  1. "Short term" recovery capability will be provided at least once per orbit in addition to landings which would occur from the pad or during powered flight prior to orbital insertion.
  2. The spacecraft will be launched within limited variations in azimuth.
  3. Communication with the crew will be available at least twice per orbit, and ground station dispersal will be such that at least one ground station will know the time and spacecraft attitude at initiation of retrosequence.
  4. Predesignated landings are to be during daylight.
  5. Whenever practical, a land landing is preferred.

Recovery capability from each orbit is considered essential to provide for emergencies associated with failure or malfunction of onboard systems, crew medical requirements or other contingencies. To meet this requirement economically, it will be necessary to establish recovery areas, each of which can handle several orbits, and which are so located as to accommodate the daylight landing requirement.

The recovery areas designated below meet these requirements, provided that a fixed launch azimuth is used. The local-time tabulations are approximations based on a launch time of 0800.

Orbit Nos.	Recovery Area	
	Land (L) or Water (W)	Local Time
1 and 16	Texas (L)	0830, 0800
2 and 17	Texas (L)	1000, 0930
3 and 18	Texas (L)	1130, 1100
4, 5, 6 and 7	Midway Island (W)	0900, 1030, 1200, 1300
8 and 9	South of Japan (W)	1000, 1130
10	Okinawa (W)	1300
11	East of Phillippines (W)	1430
12	East of Cape Verde Is. (W)	0530
13, 14, and 15	Grand Canary Is. (W)	0700, 0830, 1000

For the rendezvous mission in which final approach and docking occurs on the 15th orbit, the mission can be terminated with landing in Texas at the end of the 16th, 17th or 18th orbits.

Since small variations in the orbital ground track may result during extended missions, especially those involving rendezvous and docking maneuvers, land landings are considered feasible only for areas where the ground track passes over large flat land masses. Current spacecraft design assumptions indicate that it is not feasible to attempt land landings on small, relatively isolated islands. Many large land masses are ruled out by considerations of terrain, accessibility, or for political reasons. Therefore, water landings appear most suitable for most emergency reentries.

The recovery areas designated above are tentative; future analysis will be required to investigate the trade-offs between these and alternate areas, and to establish the recovery support requirements for those areas which are finally chosen.

The discussion above assumes that launch azimuth is constant, and neglects orbital ground path variations which may result from rendezvous and docking maneuvers. Analyses will be conducted to investigate these parameters and their implications for landing and recovery. At the present time, recovery considerations appear to make a fixed launch azimuth highly desirable, if not mandatory. This implies that the Gemini vehicle is to be launched first at the desired launch azimuth for recovery operations and the target vehicle is to be launched

second. This permits sufficient latitude in launch time, and unless prohibitive for other reasons, is a more desirable approach.

The recovery areas, designated above and/or others to be selected after subsequent analysis, are designed to handle all normal flight terminations and to provide predesignated emergency landing areas for all orbits through the eighteenth. These deferred emergency recovery areas should also suffice for longer missions since orbits in excess of fifteen follow essentially the same ground track as orbits one through fifteen. However, for missions exceeding seven days, the necessity of maintaining recovery forces on station for long periods may present additional logistic problems.

- b. Recovery from Suborbital Flight. Recovery from aborts above 20,000 feet, but prior to orbital insertion, can be handled by recovery forces deployed in a manner similar to that used for Mercury-Atlas missions. Water landing recovery areas will be predesignated after consideration of the flight and staging characteristics of the Titan booster vehicle. All pre-insertion contingencies will be investigated, and recovery operations and deployment of forces will be planned accordingly. If the high degree of reliability expected for the Titan II is realized in initial missions, it may be possible to reduce recovery force requirements for suborbital aborts.
- c. Recovery from Pad Aborts and Flight Aborts Below 20,000 Feet. For pad aborts and in-flight aborts below 20,000 feet altitude, both crewmen are assumed to be ejected horizontally from the spacecraft in crew ejection seats. The recovery problem will be one of crew retrieval, since the spacecraft itself will not be involved.

For aborts on or very near the pad, recovery will be simplified by visual observation of landing and by the small wind drift resulting from horizontal ejection at relatively low altitudes. In-flight aborts at later stages below 20,000 feet will normally result in water landing and wind drift may be greater so the crewmen may be widely separated. It should be relatively simple, however, to provide an adequate recovery force and quick pick-up, since it will be possible to track the parachutes visually.

- d. Deferred Emergency Versus Contingency Recovery. The previous discussion assumes a very high probability that landings will be made in predesignated recovery areas whether they occur from orbit, during the launch phase, or by crew ejection from the spacecraft on the pad or during early powered flight.

These predesignated areas are to be located where the probability of landings or aborts is highest. This probability must take many factors into account, among which are: spacecraft

reliability, booster reliability, tracking station location and dispersion for voice communication, telemetry and radar tracking, distance travelled subsequent to initiation of the reentry sequence, and lift and maneuvering capability after the paraglider is deployed. It is assumed that these pre-designated areas will have a deferred emergency recovery capability similar to the predesignated areas for Mercury-Atlas missions but the time to recovery may be longer in some cases than the three- to six-hour maximum for the similar Mercury areas. It appears possible to downgrade recovery operations to some extent, because of the expectation that the booster will have a greater overall reliability, and of the reentry lift and maneuver capability provided by the paraglider. Hence, both deferred emergency and contingency recovery time are left open for the present, until more thorough analysis of contributory factors can be performed.

It will still be necessary to provide recovery for landings outside of predesignated recovery areas, and contingency recovery is defined as the operations for recovery outside of these planned recovery areas.

In the following subsection, the sequence of actions required for recovery is discussed, and in some cases, differences between planned and contingency recovery are indicated.

2.2.10.2 Recovery Sequence of Actions. The sequence of activities required for recovery will not be the same for each type of recovery discussed above. However, all recovery efforts have three general phases in common: location, maintaining contact, and retrieval.

- a. Location. During on-pad and early flight aborts (20,000 feet), it will be possible to track the astronauts' parachutes visually or with radar assist, if required.

Aborts during later phases of powered flight can be tracked by Cape Canaveral and AMR down-range tracking stations. The Cape should have full knowledge of abort initiation time and paraglider characteristics so that locating the spacecraft should present no major problems.

Planned landings at predesignated areas should present no location difficulties, whether at mission termination or on other orbits, since retrosequence initiation time and capsule attitude will be known in advance or can be determined after the fact. If these parameters are known, it will be possible to predict the vehicle impact point quite accurately and to alert recovery forces.

For contingency recovery, it is assumed that a generalized landing location is made available by the GOSS (see later discussion of the GOSS responsibilities) and that the impact point may be further refined by HF/DF information, other on-board location aids, and/or by skin or plasma sheath tracking during reentry, if landing occurs in the vicinity of radar tracking facilities. Aircraft with electronic search capability, compatible with on-board electronic location aids, would then be dispatched to determine the exact landing point. In view of the low probabilities assumed for contingency landing and the uncertainties as to when these may occur, it is desirable to utilize aircraft already deployed as part of their normal mission whenever practicable, rather than to deploy aircraft world-wide specifically for contingency location operations.

- b. Maintaining Contact. The deployment of recovery forces at the predesignated abort and orbital landing areas will suffice to maintain contact for the relatively short time prior to actual retrieval. However, for contingency landings, it is desirable to plan for a fairly long lapse between capsule location and retrieval. Therefore, once contact is established, it may be necessary to deploy additional aircraft to the impact area or, if weather is unfavorable or the landing site is remote, to drop additional location aids to assure recontact.

Usually, the astronauts will be in a condition to await retrieval. Overall planning, however, should consider the use of para-rescue teams or similar techniques to render emergency assistance.

- c. Retrieval. It is assumed, for the present, that retrieval vehicles will be standing by or actually underway during the launch phase and for mission termination, and that they can be quickly dispatched in all other predesignated landing areas. This will permit very rapid retrieval from pre-orbital aborts and at mission termination. Retrieval time at other predesignated areas will vary with the advance notification of landing the recovery force receives and the distance between retrieval vehicles and the impact point.

However, no advance deployment of retrieval vehicles is planned for contingency landings, since the low probability of contingency landing and the time available for retrieval are such that normal search and rescue (SAR) procedures will be adequate. Key rescue coordination centers of SAR forces shall be briefed prior to the flight and should stand by during the flight, but no actual deployment or tie-up of vehicles should be planned.

2.2.10.3 GOSS Responsibilities. Location and recovery after seat ejection will, of necessity, be coordinated from the IMCC through the Launch Control Center or from near-site recovery forces having visual

tracking capability. For later stages of powered flight, Cape Canaveral tracking radars, in conjunction with AMR down-range stations and GOSS tracking stations, will have prime information on vehicle trajectory. This data will be routed to the IMCC for prediction of vehicle impact point. However, it is possible at this phase that the predicted impact point will be less accurate than recovery force or down-range site tracking data so it may be possible to deploy recovery vehicles prior to receipt of a predicted impact point from the IMCC.

For all non-contingency landings from orbit, retrofire initiation time and vehicle attitude at retrofire are assumed to be known in advance or to be available shortly thereafter. The GOSS tracking station(s) involved will transmit this data to the IMCC so that an impact point can be predicted. This predicted landing point will be given to recovery personnel in the IMCC who can insure localizing the recovery to a specific location. These non-contingency landings are, in essence, planned landings in which the impact point is preselected. The responsibilities of GOSS and the IMCC are to update and correct the preselected impact point on the basis of actual event initiation times, orbital parameters and other relevant factors, and to transmit the corrected landing location to recovery personnel in IMCC. The Recovery Control Center in IMCC will then choose the appropriate recovery force and transmit the corrected impact point, recovery plan, and other pertinent information.

For contingency recovery, the accuracy of predicting any impact point will depend upon the location of the reentry path relative to the range station location. Minimum information required to predict a contingency landing area with reasonable precision consists of retrorocket firing time and the number of rockets that fired. This minimum information can be provided by GOSS range stations provided that the spacecraft comes within range during reentry: Retrorocket firing can be initiated by command signal from the ground, by a retrorocket clock aboard the capsule or by the crew. Data on time of firing and the number of retro rockets fired will be transmitted to ground stations by telemetry and/or

voice whenever the capsule is within range during retrosequence or comes within range subsequently. This data, in conjunction with previous radar tracking data obtained during orbital flight, will be fed into the IMCC computing facilities for calculating the spacecraft impact point. Since this will be a calculation and radar tracking may not be available during reentry, the accuracy of prediction must be considered. It will be possible to predict the dispersion of such landings by analyzing orbital parameters, paraglider lift and maneuver characteristics and other factors, when all systems are functioning, and to arrive at the probability that landings will occur within a given elliptical area centered on the orbital ground track. The contingency may be further compounded by assuming failure of various systems, for example, the attitude control system, during reentry, in which case a larger landing area must be considered. Analyses of this type will be conducted and reported subsequently.

- a. GOSS Network. The GOSS will be responsible for furnishing radar tracking data, spacecraft telemetry and voice messages concerning retrorocket firing time, numbers of rockets fired, vehicle attitude and orbital location to the IMCC.
- b. IMCC. The IMCC will be responsible for proper data entry into computers and for informing IMCC recovery personnel of the predicted impact point.
- c. Recovery Control Center (RCC). The RCC will be responsible for choosing the appropriate recovery forces, for transmitting the predicted impact point to them, and for overall coordination of recovery operations. The RCC is assumed to be located within the IMCC building [and will have a representative located in the Mission Operations Control Room (MOCR)] but will use an independent communication network.
- d. Launch Control Complex (LCC). The LCC will not be concerned with recovery operations except for pad aborts and early in-flight aborts. For these cases, the LCC may be required to furnish information on abort time and altitude.



### 2.2.11 Summary of Functions

The preceding section served to enhance the mission phase descriptions (paragraph 1.3.2) by supplementing them with a phase-oriented list of GOSS responsibilities and modes of operation. This section serves to regroup and reorient the material in the preceding section so that it serves as a useful set of inputs to the subsequent development of the GOSS segments and action sequences.

In this regrouping/reorienting process, the five functional areas considered are Vehicle Systems (monitoring, etc.), Flight Dynamics (monitoring, advisory, etc.), Life Support and BioMedical (monitoring, advisory, etc.), Mission Command and Control, and Network and Communications Control. The following list of functions identifies these areas only implicitly.

1. The Gemini systems will be monitored during checkout and launch by the Gemini Test Conductor (paragraph 6.0) for possible hold decisions and for engineering analysis. In events which are not covered by the mission rules, the hold decision will be made by the Operations Director. If there is a change in the status of the propulsion or guidance systems, it may be necessary for the IMCC to perform computations to determine the possible effects on the likelihood of a successful rendezvous. If such computations are made, the IMCC Flight Director will make recommendations as to a hold decision or mission alteration to the Operations Director. The Agena systems will be monitored for the same reasons. Since the command schedule for the Agena will depend on the status of the Agena systems (particularly the attitude control system, the propulsion system, and the vernier thrust system), the commands and command schedule may have to be altered prior to lift-off as the result of checkout and launch monitoring.
2. The IMCC will continually maintain the propulsion status of both vehicles in terms of remaining fuel, predicted safety factor, and expected time-to-shortage.
3. The IMCC will monitor spacecraft pneumatic, life support, propulsion, navigation and guidance, attitude control, and other electronic and mechanical control systems.
4. The IMCC will provide a calibration and check of the Gemini rendezvous radar.

5. The final phases of rendezvous will be the sole responsibility of the spacecraft crew. The IMCC must provide the crew with the necessary information regarding the status and attitude of the target vehicle, and the required maneuvers necessary to effect docking. These recommendations will be based on the orbital elements of both vehicles and the attitude of the target vehicles, as well as the status of the docking devices in both vehicles. Should collision be imminent and normal docking impossible, it will be the responsibility of the IMCC to so inform the crew. If a collision avoidance maneuver should be exercised, recommendations will be made by the IMCC as to the optimum maneuver required to avoid contact after consideration of the adequate factors of safety. If a change of the orbit of the target vehicle is desired, it will be the responsibility of the IMCC to determine the appropriate commands and time of execution to the target vehicle to change its orbit to avoid collision if this maneuver cannot be controlled from the manned spacecraft. Such determinations will be based on the orbital elements and attitude of each vehicle, the energy status or reserve of each vehicle, and the possibility of a second attempt to rendezvous, should it be desired.
6. The IMCC will make a Go-No-Go decision on docking.
7. After rendezvous of the two vehicles has taken place and the desired maneuvers have been completed, it will be necessary to return the Gemini vehicle to the ground. This will involve separation of the target vehicle from the Gemini vehicle. The separation will be the sole responsibility of the crew. The FDO will be responsible for advising the crew during these phases of flight, and to initiate engine re-start or attitude control commands, as required, for the Agena vehicle to achieve the desired separation, if the spacecraft crew cannot perform this function once separation has been achieved.
8. An engine re-start command will be required. The recommendations of the FDO regarding vehicle separation maneuvers will be based on the position information of the joined vehicles, the energy status of both vehicles, and the desired time and point of reentry.
9. Any maneuvers that are desired or required during reentry will be evaluated by the FDO. His recommendations will be based on the capability of the vehicle to maneuver, on the status of the crew and critical vehicle systems, and on the real-time capability of the communication link.

10. The maneuvering during the final descent of the Gemini vehicle will be the sole responsibility of the vehicle crew. The IMCC will be responsible, however, to make recommendations as to maneuvers required during the final descent to test lifting devices or to avoid local hazards. The recommendations will be based on information received from the Recovery Control Center and available knowledge of the status of critical vehicle systems, the crew's control capability and the overall mission objectives of the flight. It is recognized that communication may not always be possible during the descent. The availability of descent communication does not affect the responsibilities (listed for planning purposes).
11. The IMCC will be in a position to make a Go-No-Go decision on Gemini insertion.
12. The IMCC will determine insertion thrust requirements for the Gemini.
13. The IMCC will monitor orbital insertion for Gemini and record insertion thrust accelerations and attitude.
14. The IMCC will determine and maintain the ephemeris of the Gemini spacecraft.
15. The IMCC will determine second-burn requirements if the insertion velocity is unsatisfactory.
16. The IMCC, in conjunction with the Launch Conductor, will determine the launch time of the Agena (assumed to be launched second) as well as the appropriate launch window. These determinations will be based on injection conditions and the resultant orbit of the Gemini and the status of both vehicles insofar as status affects the likelihood of a successful rendezvous.
17. The IMCC will also be responsible for selecting the launch azimuth of the Agena. In addition to the position and status information required, information on the capability of the recovery forces will also be required.
18. The IMCC will make a Go-No-Go decision on SECO for the Atlas.
19. The IMCC will make a Go-No-Go decision on Agena insertion after booster separation.
20. The IMCC will determine insertion thrust requirements for the Agena based on SECO status.
21. The IMCC will monitor and record insertion conditions for the Agena.

22. The IMCC will determine second-burn requirements if the insertion conditions are unsatisfactory.
23. The IMCC will determine and maintain the ephemeris of the Agena.
24. The IMCC will be responsible for determining orbit plane change requirements for the maneuvering vehicle. These plane change recommendations are defined in terms of thrust, time of application, and the proper attitude of the vehicle at the time of thrust. In the case of Agena, the IMCC will be responsible for determining the proper attitude and engine re-start commands as well as the times of transmission. In the case of Gemini (if a plane change maneuver is required), the IMCC will transmit the appropriate recommendations to the spacecraft via a remote site (typically KANO). The objective of a plane change for the Agena will be to achieve coplanarity with the Gemini.
25. In the Gemini rendezvous missions, orbital adjustments involving a change in eccentricity are anticipated. The IMCC will be responsible for determining thrust application programs to circularize an elliptical orbit or to change a circular orbit into an elliptical orbit. For unmanned vehicle orbit corrections, the IMCC will determine the appropriate commands and time of execution. Just as in the case of orbit plane changes, if the vehicle is manned, the thrust application programs to change eccentricity will probably be a series of recommended actions with the appropriate time of execution. The recommendations of the IMCC will be based on the orbital parameters of both vehicles, the particular mode of rendezvous being exercised, the energy reserve of the affected vehicle, the maneuvering capability of the vehicles, and the time at which the vehicles are in view of remote commanding sites.
26. During the final phases of rendezvous, it may be necessary to adjust the attitude of the target vehicle. The attitude-adjust commands and the time of execution will be determined by the FDO. It may also be desirable to control the attitude of the target vehicle after the two vehicles have been separated to permit the target vehicle to reenter in the desired manner. The determination of attitude control commands and the time of execution will be based on the orbital elements of both vehicles, information on the attitude, and energy status of the target vehicle.
27. The IMCC will continually maintain an abort plan which will consist of planned retrofire times for each orbit. It will be the responsibility of the FDO to evaluate the optimum time for reentry of the Gemini vehicle. The FDO will be responsible for recommending both the time of application of retrothrust and the attitude during this thrust application.

This recommendation may simply involve the initiation of a time sequence. In this case, it will be the responsibility of the FDO to determine the start time of the retrosequence and provide this to the vehicle crew, such that the reentry maneuver can take place automatically or under the control of the crew in the desired manner. The recommendations of the FDO will be based on the status of recovery forces, the conditions of the Gemini vehicle and the capability of the crew to maneuver during reentry.

28. The IMCC will continually maintain abort plans for safe minimum time returns, safe minimum energy returns, and safe minimum radiation returns. The word "safe" is intended to mean safety from a deceleration and thermal energy dissipation viewpoint.
29. The IMCC will make a Go-No-Go decision to jettison the OAMS section of the adapter.
30. The IMCC will make a Go-No-Go decision to jettison the retrosection.
31. The IMCC will make a Go-No-Go decision to jettison the docking and rendezvous cannister.
32. The IMCC will make a Go-No-Go decision on the paraglider deployment and inflation.
33. The IMCC must predict the landing point and the associated uncertainty. The IMCC must predict the landing time and the associated uncertainty.
34. The IMCC will determine the orbit capabilities of both vehicles.
35. The IMCC will determine and support an optimum attitude control program for both the Gemini and Agena.
36. The IMCC will determine and support an optimum thermal control program for the entire flight for both vehicles.
37. The IMCC will determine and support an optimum oxygen flow program for the entire Gemini flight.
38. The IMCC will determine, maintain, and recommend to the spacecraft crew a duty cycle program for the spacesuit. This program will be a schedule of utilization of the life support systems in the spacecraft and the spacesuits. Coupled with this schedule will be recommended gas constituent flow rates.
39. The IMCC will monitor possible radiation hazards to detect impending maximum dosage times to identify the requirement for abort.
40. The IMCC will determine and recommend to the crew, an optimum food consumption program for the extended Gemini missions.

41. The IMCC will monitor gas composition in the spacecraft and spacesuits for possible hazard levels of gas components.
42. The IMCC will monitor crew status and crew performance for possible mission alterations.
43. The IMCC will determine, select, and coordinate all in-flight tasks performed by the crew. Decisions to change tasks or otherwise alter the mission will be determined by the IMCC.
44. The IMCC will be responsible for the overall mission and hence will determine which, if any, maneuvers are to be performed after docking.
45. The IMCC must prepare reentry and descent acquisition messages for the recovery forces.
46. The IMCC will schedule equipment in GOSS during mission periods.
47. The IMCC will schedule data processing during mission periods.
48. The IMCC will schedule voice, data, and video loops during mission operating periods.
49. The IMCC will modify, add to, delete, or interpret mission rules.
50. The IMCC will control switching operations during mission periods.
51. The status of all stations will be determined and maintained by the IMCC.
52. The IMCC will schedule vehicle tracking and communications.
53. The IMCC will determine all command transmission schedules during mission operations.
54. The IMCC must determine acquisition data for each remote station and transmit these data to the remote stations prior to lift-off. This information should include time and pointing instructions for spacecraft acquisition (on the horizon), five degree acquisition, fifteen degree acquisition, and minimum range acquisition. The acquisition information should also include communication data resulting from the checkout and launch tests on both the Gemini and the Agena. Such communication data will facilitate the establishment of ground-to-vehicle links.
55. Prior to lift-off, the IMCC will prepare a Gemini recorder dump schedule. This schedule will be transmitted to all stations and will indicate which stations are to receive the Gemini telemetry dump and when the dump is to be made.
56. The IMCC is responsible for reporting remote site and IMCC readiness prior to lift-off.

57. The IMCC will maintain status information on all recovery forces in terms of location, assistance, and recovery periods for each designated area.
58. The IMCC will maintain a list of primary, secondary, and emergency landing sites for the purpose of planning recovery coverage.
59. The IMCC will collect and maintain surface weather information for all possible landing sites being considered. The IMCC will also collect and maintain upper atmospheric weather data for communication control and possible mission hazards.

## 2.3 SYSTEM SEGMENTS

### 2.3.1 General Criteria

Gemini Project operations could be broadly described as a set of a few basic mission functions, performed by a group of individual physical facilities performing coadunately. Alternatively, they could be described as a basic set of physical facilities, coordinated to carry on certain mission functions. On the one hand, the system might be segmented by mission function while, on the other hand, segmentation is by physical facility. Analysis of the system for both its conceptual and its operational development, and ultimately for its implementation, must be broken down into segments of some type. When such segments are carefully chosen, well defined, and their nature clearly understood, they become system subdivisions which can be considered separately.

Dividing a system into such segments is most useful when the nature of each segment is clearly defined, understood and accepted by all persons who must work with the system, performance of analysis, development, operation or construction.

It soon becomes evident that adherence to a strictly functional subdivision of the system is no more possible than is a strictly locational or geographical one. It is also readily apparent that adoption of two completely separate approaches, one functional and one geographical, is untenable. The most satisfactory solution is to divide on both bases simultaneously, physically identifying functional entities. Of course, it is seldom possible to accept literally this ideal approach, but compromises usually are satisfactory. Compromises are most often effected by judiciously redefining or subclassifying functions, with a corresponding regrouping or subdividing of facilities at certain geographical locations. Thus, without changing either basic concepts or methods of physical implementation, the system can be divided into a set of several identified segments or subsystem groupings which can be readily accommodated.



Using this approach, the system to be utilized by the Gemini Project to perform its missions, is composed of twelve basic segments. Listed in paragraph 2.3.2 are four segments, derived from what can be called the Flight System and eight segments from the Ground Operational Support System. Paragraph 2.3.3 outlines the reasons for selecting these twelve. Paragraph 2.3.4 shows an elementary view of the information links connecting the segments.

2.3.2 Basic Segments List

- a. Flight System
  - 1. Titan II Booster
  - 2. Gemini Spacecraft
  - 3. Atlas Booster
  - 4. Agena Spacecraft
- b. Ground Operational Support System
  - 1. Integrated Mission Control Center (IMCC)
  - 2. Launch Control Center (LCC)
  - 3. Launch Tracking Stations (LTS)
  - 4. Range Safety Office (RSO)
  - 5. Recovery Control Centers (RCC)
  - 6. Recovery Command Posts (RCP)
  - 7. Recovery Forces (RF)
  - 8. Remote Stations (RS)

### 2.3.3 Selection Rationale

At first view, major subdivisions of the Gemini Project operations were thought of as composed of six parts, split on a purely functional basis:

- Gemini, the manned spacecraft
- Agena, the unmanned spacecraft
- IMCC, the central control
- LCC, for vehicle launching
- RCC, for crew recovery
- Remote Stations, for contact between the ground and the spacecraft.

As more serious consideration is given to functional analysis of the total system, these are found to be inadequate, for a number of reasons. First of all, it is convenient to make a clear-cut division of both the Gemini and Agena vehicles, each into two parts: the booster and the spacecraft. Although the boosters may not be considered at all, after the spacecrafts are in orbit, both parts of each vehicle are basic functional entities until orbit insertion does occur. Thus, to the Gemini is added the Titan, and to the Agena is added the Atlas.

Beyond the control and mechanics of preparing and lifting each vehicle to its orbit, the LCC has one major functional responsibility warranting explicit recognition as a separate system segment. This is the tracking function during the powered-flight phase and can be named the Launch Tracking Stations, or LTS. This tracking responsibility is somewhat different from that of the Remote Stations for orbital operations, and the stations performing the launch tracking will be physically located within the Atlantic Missile Range.

Examination of the problems of rigidly controlling the safety of ground personnel, both within the AMR and in surrounding populated areas, reveals the necessary existence of the nearly autonomous function, the Range Safety Office. Because of its unique functional independence, it emerges as a distinct system segment.

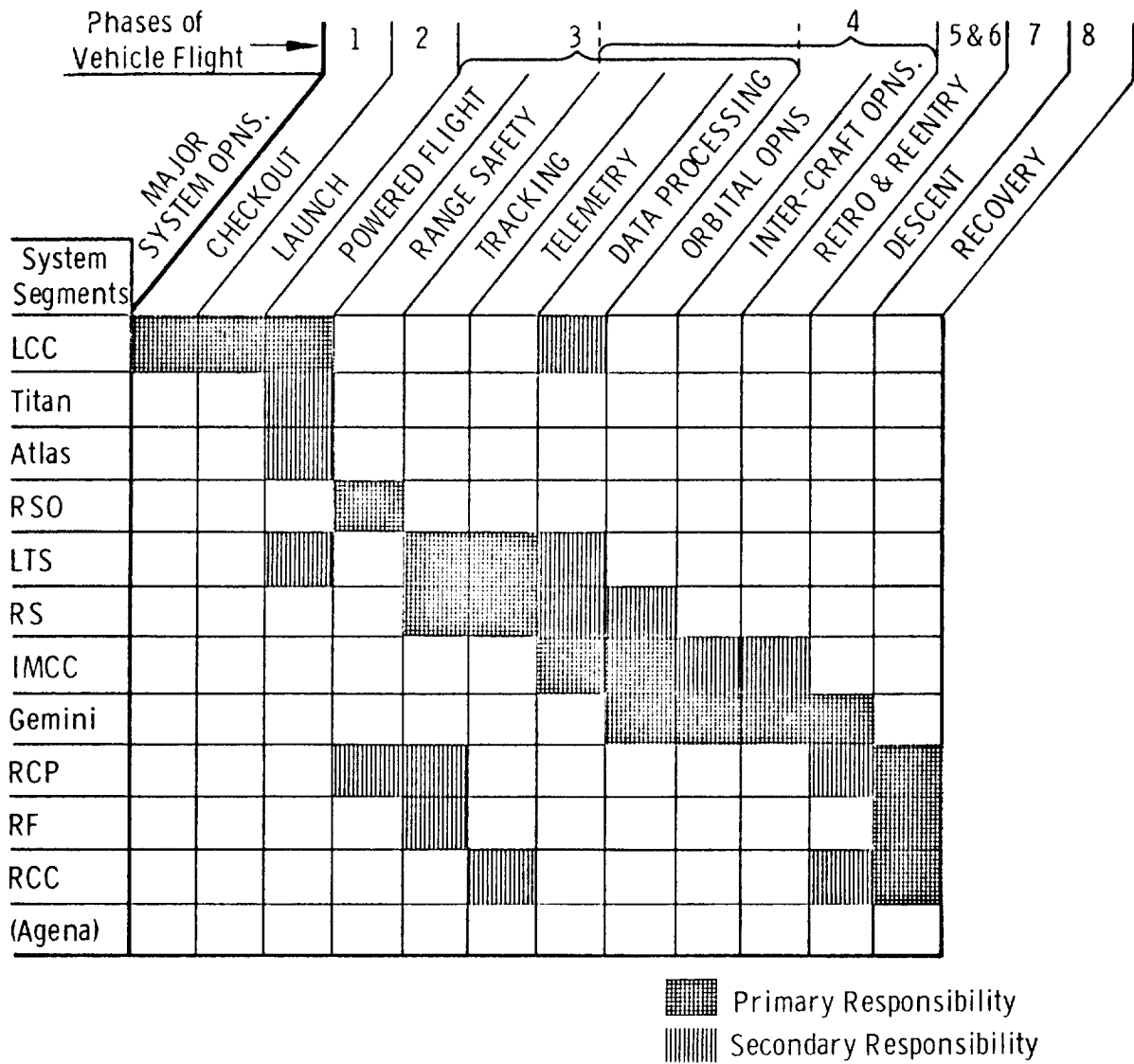
2.3.3-1

The actual center for recovery control resides physically within the IMCC, but the impact of the functional activity of the RCC is felt primarily in two other areas. One can be designated the Recovery Command Posts, RCP, foci of recovery control information for specific predesignated broad geographic areas. The other can be called the Recovery Forces, RF, the recovery units which perform the actual physical recovery functions of retrieving the crew and spacecraft; these are directly controlled by the RCPs.

The IMCC remains the segment originally envisioned, as do the Remote Stations, RS. It is recognized that perhaps more than any other segment, the RS is really no more than a remote sensory extension of the IMCC. Its principle duties of keeping track of the spacecrafts in orbit and linking them to IMCC for communications are not nearly so functionally distinct from the IMCC as are, for example, the primary duties of the launch and the recovery segments. This fact is clearly apparent under certain planned contingency situations where provision is made for certain Remote Stations to actually assume control of ground-space operations -- for example, when communication outages occur between IMCC and RS.

Figure 2.3.3-1 shows the functional responsibilities maintained by system segments for major system operations. If, at any time during a Gemini mission, a system segment has functional responsibility for a major system operation, the chart has been shaded accordingly. Heavy shading indicates that this responsibility may extend to a primary one, while light shading indicates that such responsibility is never to be more than a secondary one. A fairly good correlation between operational and locational selection of segments is indicated by the general linear trend of the diagonal shading, with functional overlap showing up as dispersion from this "line," especially where secondary responsibilities are concerned.

Table 2.3.3-1 illustrates, in more detail, functional overlaps between LTS, RS and RCP and RF. As a matter of fact, an individual remote station can be considered to assume a different segment character depending upon which period, or phase, of the mission is in progress.



10092-P

Figure 2.3.3-1 Major Functional Responsibilities of System Segments

2.3.3-3

<u>Possible Remote Stations For Launch, Orbital &amp; ReEntry Contact With Spacecrafts</u>	<u>Functions</u>							<u>Periods of Service</u>	
	<i>Atlas / Agena</i>	<i>Titan / Gemini</i>	<i>Command</i>	<i>Atlas / Agena</i>	<i>Titan / Gemini</i>	<i>Telemetry</i>	<i>Gemini Voice</i>	<i>Launch</i>	<i>Orbital</i>
Cape Canaveral	•	•	•	•	•	•	•	•	•
Patrick A.F. B.					•		•		
Great Bahamas Isl.			•		•		•		•
Eleuthera Isl.					•		•		
San Salvador Isl.					•		•		•
Grand Turk Isl.			•		•				•
Bermuda			•	•	•	•	•	•	
Atlantic Ocean Ship		•	•	•		•	•	•	
Canary Islands	•	•	•	•	•	•		•	
Kano			•			•		•	
Zanzibar			•			•		•	
Indian Ocean Ship			•			•		•	
Muchea		•	•	•	•	•		•	
Woomera			•		•	•		•	
Canton Isl.			•			•		•	
Hawaii	•	•	•	•	•	•		•	
Pacific Ocean Ship	•	•	•	•		•		•	
So. California *			•	•	•	•		•	•
Guaymas			•	•	•	•		•	•
White Sands *					•				•
West Texas					•	•			•
Houston	•	•	•	•	•	•		•	
South Texas			•		•			•	
Eglin A.F. B.					•			•	•

\* It is anticipated that the many radars, (Approximately 32 in number) spread between these two sites, can be made available for reentry to land touch-downs in Texas.

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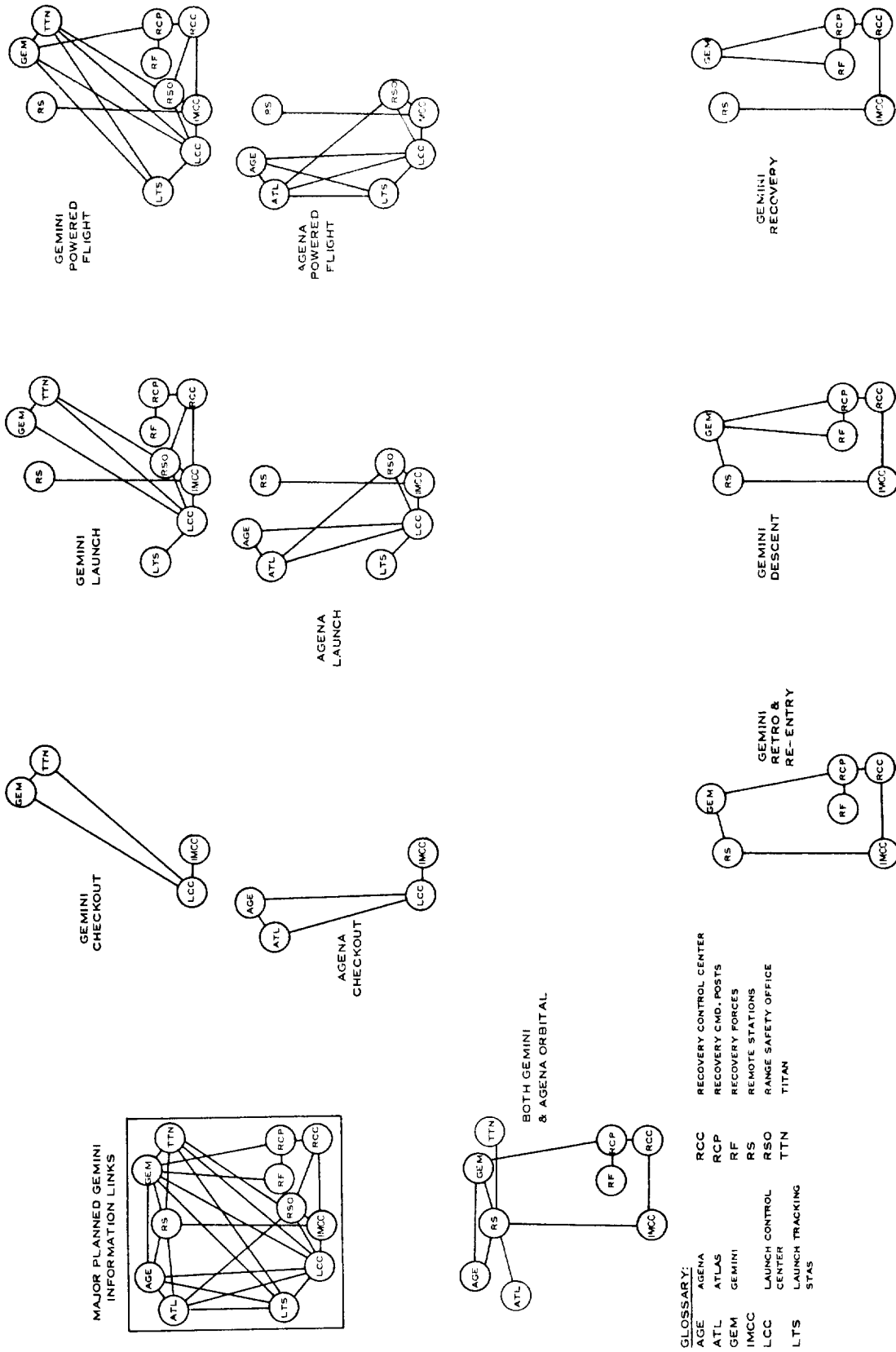
Table 2.3.3-1 Distribution of Functions Among Remote Stations

2.3.3-4

#### 2.3.4 Inter-Segment Links

Between the system segments, there are expected to be major information flow paths or links. Not all of these will be used simultaneously, but various links will come into and out of play during the several phases or during different times of the same phase of a mission. Figure 2.3.4-1 illustrates this fact, showing in one group the major links planned, along with separate pictures of the links, which can be expected to function during each of ten phases of mission activity:

Gemini Checkout	Agena Checkout
Gemini Launch	Agena Launch
Gemini Powered Flight	Agena Powered Flight
Both Gemini and Agena Orbital	
Gemini Retro and Reentry	
Gemini Descent	
Gemini Recovery	



2.3.4-2

Figure 2.3.4-1 Gemini Project Major Information Links



## SECTION 3

### REQUIRED INFORMATION

#### 3.1 ACTION AND DECISION SEQUENCES

The functions that have been developed are divided arbitrarily into two main categories: continuous and discrete. Continuous functions refer to those GOSS activities which are procedurally invariant throughout the entire mission. Examples of these functions are the monitoring functions. Discrete functions, on the other hand, have well defined time spans and terminate at either specific times or when specific events occur. Examples of these functions are the flight dynamics functions involving recommended plane changes or engine restarts.

The continuous functions are currently being examined as continuous IMCC processes. Each of these processes will be described in sufficient detail to identify the information requirements considered necessary to insure the proper performance of the processes. The discrete functions are also being examined as specific decision sequences.

It is important to make two distinctions at this time. Both kinds of functions, continuous and discrete, actually have two types of flow. One is referred to as nominal and the second is referred to as perturbed. The nominal flow is defined on a statistical basis in terms of bounds. As long as the mission (and the information describing the mission) is proceeding within certain bounds, the planned sequences of events and actions remain uninterrupted. For example, as long as an orbital correction is within predefined limits, the mission is considered as proceeding in the nominal mode or flow. If, on the other hand, these bounds are exceeded such that the planned sequences are altered or interrupted, and an alternate course of action must be pursued according to mission rules, then the mission is considered perturbed. This is

reflected as a branch point in a flow diagram. The term contingency is being reserved for defining situations which may occur and for which appropriate actions are not prescribed by mission rules or other precedents. The development of action and decision sequences which are currently under investigation will reflect the above distinctions.

### 3.2 INFORMATION SINKS

If, at the time of lift-off, there exist alternatives as to which actions should be taken, an information sink is considered to exist. It is therefore assumed that given sufficient information during the mission, a single action will be evident. There may be two action alternates (e. g. , a Go-No-Go decision) or a continuum of alternates (e. g. , a recommended correction). As the sequences are developed the information sinks will be identified and referenced by mission phase, location, and function.

### 3.3 INFORMATION REQUIRED TO FILL SINKS

For each identified sink, the necessary and sufficient information requirements will be specified. To facilitate the support of parallel design and planning efforts for the IMCC, a preliminary analysis was performed to develop a first iteration on the information requirements. This analysis was not based on an investigation of the action and decision sequences which are just beginning to be developed. The functions were grouped into seven categories which have been developed for the preliminary manning concept present in paragraph 6. The categories are:

- a. Flight dynamics
- b. Vehicle systems
- c. Life support and biomedical
- d. Network communication and tracking
- e. Operations and procedures
- f. Launch systems
- g. Recovery systems

Each of these categories also corresponds to functional groups within the IMCC. Each of these groups is charged with the responsibility (1) to detect and eliminate or to avert any undue risk to the spacecraft crew (2) to detect and eliminate or to avert any abortive conditions, (with respect to the flight plan) and (3) to recommend alternate missions when minor malfunctions occur. Hence, the information flow requirements reflect the data inputs and data/command outputs of each group in the discharge of its responsibilities. The requirements which follow are based on Project Mercury experience, expert opinion, and logical extension of these sources.

These statements of information requirements are presented in tabular form to permit rapid identification of the area of analysis and the technique to be used. When the action and decision sequences are developed, the flight profile becomes firm and the final spacecraft design evolves, these requirements will be added to, modified, or combined as necessary.

### 3.3.1 Flight Dynamics

3.3.1.1 General. This section presents an itemization of the first iteration on the information requirements associated with flight dynamics in the Gemini rendezvous missions. This information is a tentative listing of those requirements considered necessary, although not necessarily sufficient. These functions have been used to develop the following requirements.

3.3.1.2 Information Requirements. The dynamics requirements have been subdivided into five categories:

- a. Sequence event information
- b. Special event information
- c. Status information
- d. Time measures on mission events
- e. Function information.

Final determination of all the requirements may suggest different categorization of the requirements. Examples of such categories could be source, destination, links over which the information flows, functions which require the information, type of information (biomedical, guidance, etc.), and times of information flow. These different categories will all be used when they better identify the requirements. The breakdown for this report was selected for convenience of presentation.

- a. Sequence Event Information. A tentative list of requirements for event information is presented below. Table 3.3.1-1 summarizes the sequenced event information and identifies the phases of the mission during which each of the events occur.
  1. Titan/Gemini Liftoff. This term denotes the first stage ignition of the Titan, the return of direct flight control from the LCC to the IMCC, and the liftoff of the Titan/Gemini vehicle.

Table 3.3.1-1

FLIGHT DYNAMICS SEQUENCE EVENT INFORMATION

PHASES AND SUBPHASES OF FLIGHT

Sequence Event Information	Checkout & Launch	Powered Flight	Rendezvous, Orbital Docking, Etc.	Retro Reentry	Descent	Recovery
Titan-Gemini Liftoff	x					
First Stage Cut-off		x				
First Stage Jettison		x				
Second Stage Cut-off		x				
Second Stage Jettison		x				
Orbit Insertion		x				
Atlas-Agena Liftoff	x					
BECO		x				
SECO		x				
Agena Separation		x				
Agena Plane Change			x			
Rendezvous Radar ON			x			
Docking Mech. Extend			x			
Gemini-Agena Contact			x			
Docking Complete			x			
Docking Mech. Retract			x			
Agena Separation				x		
Equip. Section Jettison				x		
Retrofire #1, #2, #3, #4						
Retro Package Jettison				x		
Dock. & Rend. Hous.						
Jettison				x		
Droque Chute Deployment					x	
Paraglider Deployment						
& Inflation					x	
Skid Extension					x	
Gemini Landing					x	x
Agena Re-Entry			x		x	x

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2. First Stage Cut-Off
3. First Stage Jettison - Second Stage Ignition
4. Second Stage Cut-Off
5. Second Stage Jettison
6. Orbit Insertion. This term denotes a change in the spacecraft mode of operation. The mode changes from a launch mode to an orbit mode with the corresponding change to greater crew control capability.
7. Atlas/Agena Liftoff. Just as in the case of the Titan/Gemini, this event is identified by booster ignition, the start of powered flight, and the return of direct flight control to the IMCC.
8. BECO (booster engine cutoff)
9. SECO (sustainer engine cutoff)
10. Agena Separation. This term denotes the separation of the Agena from the boost vehicle. It also denotes the onset of the orbit mode of flight for the Agena.
11. Agena Plane Change. Once the Agena has achieved orbit, the next major event is the plane change maneuver to achieve coplanarity with the Gemini. Information regarding the plane change will indicate that the Agena engine has been restarted and the plane change effected.
12. Rendezvous Radar "ON." The rendezvous preparation subphase commences when the rendezvous guidance radar in the Gemini "locks on" the Agena. It is expected that the vehicles will be separated by approximately 250 nautical miles when this event occurs.
13. Docking Mechanism Extended. The extension of the docking mechanism from the Gemini indicates that one required docking condition exists. This event signals start of the docking subphase.
14. Gemini/Agena Contact. This refers to the engaging of the docking mechanisms.
15. Docking Complete. Once the vehicles have made contact, it is necessary to lock the vehicles together and make the electrical connection so that Agena can be controlled from the Gemini spacecraft. The event "docking complete" implies that the two vehicles have been connected and orbital maneuvers can be executed by the combined Gemini-Agena vehicle.
16. Docking Mechanism Retract. This event is simply the reverse of the extension event. The retraction of the docking mechanism denotes that the two vehicles are merely in contact and not locked.



17. Agena Separation. Following the retraction of the Gemini docking mechanism, the Agena and the Gemini will be physically separated so that the Gemini may retrofire and reenter.
  18. Equipment Section Jettison. The aft portion of the Titan/Gemini adapter must be separated by an explosive charge before the retrograde rockets are exposed. The equipment section jettison denotes a necessary condition for safe retrofire.
  19. Retrofire #1, #2, #3, and #4
  20. Retro Package Jettison. Before the spacecraft reenters, the remainder of the Titan/Gemini adapter containing the retro rockets must be separated. This event denotes one safe condition for reentry.
  21. Docking and Rendezvous Housing Jettison
  22. Droque Chute Deployment
  23. Paraglider Deployment and Inflation. This is actually a four-event sequence: aft section of paraglider releases; partial inflation; forward cable releases; and full inflation.
  24. Skid Extension. (right, left, and nose skid)
  25. Gemini Landing
  26. Agena Reentry. Once the Gemini has landed and has been recovered, the Agena may be commanded to reenter. The particular significance of this event information will depend on the desired actions after the Gemini vehicle has been recovered.
- b. Special Event Information. There are five special events which have been identified as information requirements. It is implied that knowledge of these events will be necessary. No sequence is implied by the ordering. Table 3.3.1-2 summarizes the requirements.
1. Capsule Abort. This event signifies that the Gemini crew has decided to abort the mission. This may require early reentry, seat ejection or both, depending on the timing of the decision.
  2. Mayday. This event is analogous to the capsule abort event except that it denotes an abort decision has been recommended by the IMCC.
  3. Range Safety Abort. The decision of the Range Safety Officer to abort the mission will result in an event indicating intent to abort.

Table 3.3.1-2  
SPECIAL EVENT INFORMATION

Special Event Information	PHASES AND SUBPHASES OF FLIGHT					
	Checkout & Launch	Powered Flight	Orbital	Rendezvous, Docking, Etc.	Retro	Reentry
Capsule Abort	x	x	x	x	x	x
Mayday	x	x	x	x	x	x
Range Safety Abort	x	x				
Ejection Seat Initiate (left)		x				x
Ejection Seat Initiate (right)		x				x

4. Ejection Initiate (left.) This event indicates that the left ejection seat has been fired.
  5. Ejection Initiate (right.) This event indicates that the right ejection seat has been fired.
- c. Status Information Requirements. This section presents a tentative list of status information usable to support flight dynamics. Some of the items may require a group of information concerning numerous parameters while others require several decimal digits only. These determinations will be made explicit in later revisions of this report. The current list should be interpreted as a tabulation of status information requirements only.
1. Orbit Capability. This information identifies the number of complete earth orbits the vehicles (Gemini and Agena) can make.
  2. Recovery Area Normal. This area is defined as the predicted landing area if the remainder of the mission proceeds as planned.
  3. Recovery Area (Immediate Return.) This area is the estimated landing area if the retro and reentry sequences are initiated immediately.
  4. Recovery Area (Deferred Emergency Period.) It is assumed that there will be a definite number of planned mission termination points dictated by ground coverage and recovery considerations. Plans may exist for a deferred emergency return (reentry) once per orbit. It is likely that there will be more than one opportunity per orbit for an emergency return. These emergency returns then define deferred emergency reentry periods. If it is desired to terminate the mission early, the retro and reentry sequences will be initiated at the next planned time for a deferred emergency return.
  5. Insertion Altitude. The altitude of the vehicles at the time powered flight terminates is called the insertion altitude. This information is required from both the Gemini and the Agena.
  6. Degree of Plane Change Required. After the insertion of the Agena, it has been assumed that a plane change may be required to achieve coplanarity between the Gemini and Agena orbit planes. The number of degrees of plane separation on Agena insertion is considered required information.
  7.  $\Delta V$  Required for the Plane Change. This information refers to the velocity increment required to effect the plane change.

8. OAMS Status. The status of operation of the Orbit Attitude and Maneuvering System should be known during the mission. The form of this information has not been determined. The utility of information on propellant storage, condition of controls, or information on injector head temperatures has not been determined yet.
9. OAMS Control Fuel Status -  $\Delta V$  Remaining. The remaining velocity change capability of the OAMS must be known during a rendezvous mission.
10. RCS Status. Just as in the case of the OAMS, the status of both Reaction Control Systems should be known. The required status parameters have not been determined at this time.
11. RCS Control Fuel Status - Time Remaining. In addition to the status information, the time or percent of fuel remaining must be known for both Reaction Control Systems.
12. Attitude Control System - Gemini. The operability of the Gemini attitude control system is designated as an information requirement. The vehicle response to the attitude control system must be known.
13. Attitude Control System - Agena. The operability of the attitude control system of the Agena must be determined. This information should include the percentage fuel remaining for attitude corrections.
14. Agena Propulsion Status. This requirement includes the general operability of the main engine and the  $\Delta V$  (or velocity change capability) remaining.
15. Guidance System Status. The status of both the Gemini and Agena guidance systems is required.
16. Expected Rendezvous Point. The information regarding the time/space position of rendezvous will be required to support the flight dynamics functions in the GOSS.
17. Velocity Change Required for Rendezvous. The velocity increment required to effect rendezvous is also required. Included within this information requirement is an indication of the percentage fuel remaining to effect rendezvous.
18. Velocity Requirements for Collision Avoidance. If collision is imminent and not desired, there is an information requirement for the  $\Delta V$  necessary to safely avoid collision.
19. Docking Status. There is a requirement for information about the docking status of both the Gemini and the Agena, since the status affects the likelihood of a successful rendezvous and the safety of the crew.

20. Vehicle Attitude. The attitude information of both vehicles will be required to support the flight dynamics functions in GOSS.
  21. Contacts Scheduled. The ground contacts expected with the vehicles must be identified by time, location, and expected duration of the contacts. Acquisition information will also be required.
  22. Ejection Seat Mode. Information as to whether the seat ejection system is on manual or automatic control, is required.
- d. Time Information. Time information is viewed as an index or a measure associated with specific events which will occur with certainty, or which are considered sufficiently likely to merit concern. Time information as a measure can be either actual time or predicted time. At the time of lift-off, there will exist a plan for all mission events and, consequently, the existence of a time measure is implied. An example would be the time to retrofire.

It is important to bear in mind that the GOSS, as an entity, deals exclusively in information. The inputs are information and the products or outputs are information. What makes the GOSS so complex is the time and accuracy constraints imposed on the outputs. The system will be paced by time and constrained by time. All actions, decisions, and events will carry time tags. A series of times which will be required at specific points within the GOSS in various forms and accuracies, includes:

1. Launch count - Titan/Gemini
2. Launch count - Atlas/Agena
3. Gemini vehicle time
4. Agena vehicle time
5. Time to rendezvous radar control
6. Time to collision avoidance maneuvers
7. Time to docking
8. Time since docking
9. Time to Gemini-Agena separation
10. Time to retrofire
11. Time since retrofire
12. Time to retrofire (current deferred emergency period)
13. Time to next Agena restart

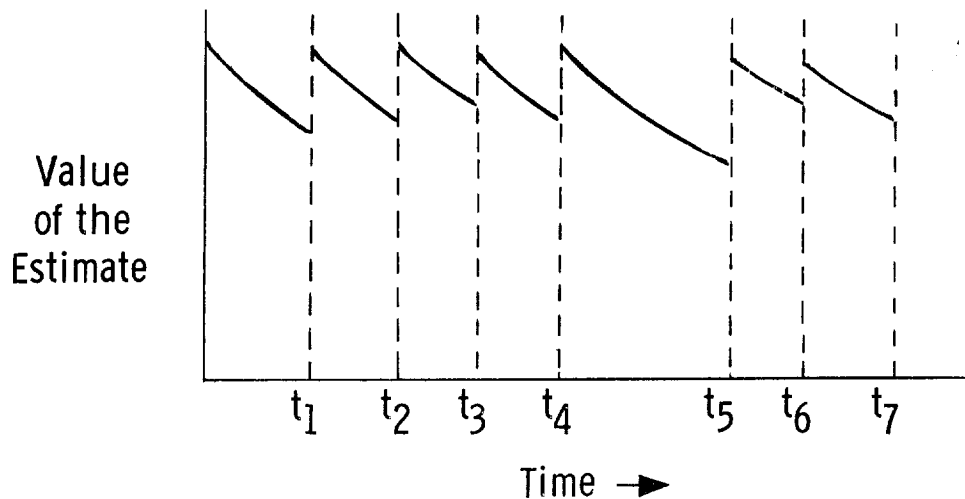
14. Time to next scheduled ground contact
15. Expected duration of next ground contact
16. Time to landing.

Detailed studies are being initiated to determine which time measures should be available to each individual and in each piece of equipment in the GOSS. The more difficult determinations involve the manner in which time is measured. We have mentioned that all events can be assigned explicit time tags at the time of lift-off. These times, as well as times generated in any other manner, are estimates.

The difficulty in information planning for time data is the determination of the kind and quality of estimate required. The fallibility of equipments and the lack of knowledge about natural physical forces fosters human distrust or loss of confidence in estimates which are based on something other than the most recently-acquired information. The determination of requirements for time estimates reflects a sequential process, analogous to classical sequential estimation with the added complication that the age of the data affects the quality (or distribution) of the estimate. Data does not come without cost. Consequently, we are faced with tradeoff problems at this early stage of planning.

It is possible to conceptualize a model of the time estimation problem. This model indicates the approach that is being followed in specifying certain time information requirements.

The model can be illustrated by a simple example. Let the requirement in question be TIME SINCE RETROFIRE. For purposes of illustration, it is assumed that retrofire can occur at any time during orbital flight. The following chart depicts the time history of the estimate of the time since retrofire. At the times  $t_1, t_2, \dots$ , new data is obtained on which to base the estimate. The times  $t_1, t_2, \dots$ , are intentionally distributed in a non-uniform manner to show the effect of varying gaps and to indicate an analogy to ground contacts with the vehicle.



Once the vehicle is contacted by the ground and new data is received, the value of the estimate has a step increase. The confidence in the estimate and, correspondingly, the value of the estimate decrease rapidly until new data is received which verifies or changes the estimate. This follows from the fact that, if retrofire occurs between scheduled contacts, the value of the last estimate decreases as the age of the estimate increases. For example, knowing that the time to retrofire was a certain value on the last contact is less useful (in terms of uncertainty in landing area) if the last contact was an hour ago than if it were thirty minutes ago simply because retrofire could have occurred at any time since the last contact. If a contact with the vehicle is made after retrofire occurs and that contact produces no new time data, the value of the contact, and hence the estimate, will not increase stepwise as with previous contacts which produced a new estimate. The value of the estimate can be measured in terms of the uncertainty of the landing area. This simplified model can identify the technique for specifying the information requirement for time since retrofire. In this case, a maximum update cycle on the time estimate and the value function for a cycle time would have to be specified so that tradeoffs could be properly made as the need arises.

Similarly, a curve relating value and accuracy for a given update cycle could be generated. Such a model would provide the basis for specifying the desired accuracy of the information requirement. The model could indicate the minimum value of the estimate. If this value were unsatisfactorily low, consideration should be given to filling the largest contact gap with an added station or changing the method of estimation. The final version of this report will present the results of such analyses.

- e. Function Information. There will be specific requirements for special function information to support the flight dynamics functions of the GOSS. The term function information is used to denote a requirement for the functional relationship between two parameters of the spacecraft flight. The following is a tentative list of such requirements:

1. Orbit altitude (Gemini) vs. time
2. Orbit altitude (Agena) vs. time
3. Range between vehicles vs. time
4. Rate of closure between vehicles
5. Central angle difference between vehicles vs. time
6. Minimum clearance (miss distance) vs. applied  $\Delta V$  for collision avoidance
7. Altitude vs. range (pre-insertion)
8. Track deviation vs. time
9. Velocity vs. altitude (pre-insertion)
10. Gamma angle (pre-insertion)
11.  $V/V_r$  (velocity deviation)
12. Eccentricity vs. time
13. Longitudinal acceleration vs. time
14. Inertial velocity vs. time

Each of these requirements will be analyzed in detail to determine:

1. The necessity and sufficiency of the information
2. The required accuracy of the information
3. The tolerable time delays on the information
4. The required form of the information
5. The times and locations at which the information is desired.



### 3.3.2 Vehicle Systems

3.3.2.1 Vehicle Systems/Gemini. The vehicle systems functional group of the GOSS/IMCC consists of a systems monitoring function in the MOCR, a systems monitoring/advisory function in the MOCR staff area, and a systems monitoring function at the remote sites. The actual flow of information is considered as originating at the vehicle, proceeding to the remote site and from there to the MOCR and its support area. It is envisioned that information filtering will take place as the flow proceeds to the floor of the MOCR. The filtering processes, however, are a part of the information flow plan. The requirements developed herein are for the composite group of vehicle systems information items. Assignment to specific areas within the group has not been attempted. The data requirements for a vehicle system monitoring function are presented in Table 3.3.2-1, under the following subfunctions:

- a. Sequencing data
- b. Guidance data
- c. Propulsion/attitude stabilization
- d. Instrumentation and communication
- e. Environmental data
- f. Structures data
- g. Power system data

Environmental data refer to readouts of any sensors of cabin or suit temperatures, pressures, gas content, etc. Structures data are concerned with the condition of the spacecraft during any mission phase, e. g., "have the booster and spacecraft separated?", "have the retrorockets been jettisoned?", etc. Propulsion/attitude stabilization refers to the readout of, for example, roll, pitch and yaw sensors. Instrumentation and communication data are required by those groups monitoring electronic system performance.

Data, perhaps unique to rendezvous missions, are concerned with guidance during orbital maneuvering and consist of on-board guidance computer readouts. The sequencing data are simply indications of the state of all clock- or on-board, transducer-controlled equipments within the spacecraft, and, finally, the power data reflect the condition of batteries, fuel cells, etc. This tabular presentation includes operational (as opposed to engineering) justifications for each entry. The justifications are based primarily on expert opinion\* and extensions of Project Mercury information. To complete the presentation, a cursory estimate of tolerable delays and accuracy is included in the Tables.

3.3.2.2 Vehicle Systems/AGENA. During "orbital" missions of Gemini, the vehicle systems functional group supplies a monitoring/advisory function for a single spacecraft. During a rendezvous mission, however, the monitoring/advisory function is for two spacecraft: the Gemini and the Agena. Hence, the vehicle systems discussion must be expanded to include the information flow requirements added by the inclusion of the Agena in the flight plan.

The tabular form of presentation developed for the Gemini vehicle systems is continued in Table 3.3.2-2, unchanged in form and meaning, in this supplementary section. Note that many more of the flow requirements are designated as "class A" (essential to the mission) inasmuch as the Agena lacks the primary human-operator control which is present in the Gemini. In addition, emphasis on "class C" (post-flight analysis data) is slightly greater because the human memory and transducer is not available. Therefore, telemetered data is the only substitute.

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\*For example; M. I. T. Lincoln Laboratory: "A Ground Environment for the Apollo Mission," AP-3; McDonnell Aircraft notes on "Gemini Parameters for Display in Range Stations"; and Gemini Project Office notes on "Agena Instrumentation."

3.3.2.3 Categories of Information. To make the information flow requirements in Tables 3.3.2-1 and 3.3.2-2 more tractable, it is expedient to define three categories of information. Inherent in these definitions are the justifications for the information requirement which they describe. Implicit in the definitions are priorities for the information flow for both up and down links (thus establishing three realms of tolerable delays from 0 seconds to several days.) The three definitions also form the basis for tradeoff decisions, when and if such decisions are required in the course of developing the information flow plan. The definitions are:

- a. Information Flow Essential to the Mission. This category is comprised of information transmission(s) which require processing or decision exceeding the capability of the spacecraft crew. Most often this category of information is found in ground/spacecraft real-time command/control loops. Certain orbital control and adjustments, primary timing, and calibrations are examples of this category of information.
- b. Information Flow Required for Contingency Backup. Maximum contingency coverage is mandatory to protect the crew and spacecraft, upon which world-wide attention will be focused. Information flow from sensors which monitor all essential spacecraft subsystems falls in this category. On the ground, this information will be filtered for negative behavior (system performance outside specified limits) and processed to determine the corrective course of action.
- c. Information Flow Required for Engineering Analysis. This class of information results from specialized experiments, data for publicity purposes and information of value to analysis in the event of catastrophe. This category has a lower priority than a or b, yet if it is required for unforeseen contingency analysis, it must also be available in the same time reference as b above.

Table 3.3.2-1  
GEMINI INFORMATION REQUIREMENT

Vehicle Gemini	Information Requirement	Comments on Accuracy	Mission Phase(s)	System Sequencing			Remarks
				A	B	C	
"Clock(s) started" verification		+0.1 sec. in time of occurrence	Launch	x	x		Ground control verification
Launch vehicle first stage cutoff		+0.1 sec. in time of occurrence	Launch	x			
Launch vehicle second stage cutoff		+0.1 sec. in time of occurrence	Launch	x			
Capsule elapsed time		+ 1/2 sec.	All		x		Ground control verification
Time to OAMS maneuver		+ 1/2 sec.	Orbit,		x		
Time to retro-sequence		+ 1/2 sec.	Reentry	x			Needed for recovery area preparation
.05g sensed		+ 1/2 sec. in time of occurrence	Reentry		x		
Main chute deployed		+ 1/2 sec. in time of occurrence	Reentry		x		
Paraglider deployed		+ 1/2 sec. in time of occurrence	Reentry			x	
			Reentry			x	

Table 3.3.2-1 (Contd)

Vehicle Gemini	Information Requirement	Comments on Accuracy	Mission Phase(s)	System Guidance			Remarks
				A	B	C	
	Vertical platform	$> +1/2^\circ$	Orbit.	x			Supplements OAMS Data
	Along Track Platform	$> +1/2^\circ$	Orbit.	x			Supplements OAMS Data
	Cross Track Platform	$> +1/2^\circ$	Orbit.	x			Supplements OAMS Data
	Airspeed		Reentry	x			Real time ground Control of lift Reentry Vehicle
	Angle of Attack	$> +1^\circ$	Reentry	x			
	Density Altitude		Reentry	x			

Table 3.3.2-1 (Contd)

System Propulsion/Stabil.Vehicle Gemini

Information Requirement	Comments on Accuracy	Mission Phase(s)	Category			Remarks
			A	B	C	
OAMS Fuel Quantity	1% F. S.	Orbit, reentry	x			All OAMS TLM require real time capability due to ground control of orbital maneuvering
OAMS Oxidizer quantity	1% F. S.	Orbit, reentry	x			
Helium Pressure (unreg.)	Sufficiently acc. to backup "fuel qty"	Orbit, reentry	x		x	
Helium Pressure (reg.)		Orbit, reentry	x			
OAMS Thruster Temp.		Orbit, reentry	x			
RCS System #1 Propellant Condition	Sufficiently acc. to backup fuel qty. meas.	Thru reentry		x		
RCS System #2 Propellant Condition		Thru reentry		x		
N <sub>2</sub> Pressure, Sys. #1 (Unreg.)		Thru reentry		x	x	

3.3.2-6

3.3.2-7

Table 3.3.2-1 (Contd)

Vehicle Gemini System Propulsion/Stabil. (Contd)

Information Requirement	Comments on Accuracy	Mission Phase(s)	Category			Remarks
			A	B	C	
N <sub>2</sub> Pressure, Sys. #2 (Unreg.)		Thru reentry		x	x	Supplements OAMS Data
N <sub>2</sub> Pressure, Sys. #1 (Reg.)		Thru reentry		x	x	
N <sub>2</sub> Pressure, Sys #2 (Reg.)		Thru reentry		x		
RCS Thrustor Temperature(s)		Thru reentry				
Pitch Attitude	+ 1/2°	Thru reentry	x			
Roll Attitude	+ 1/2°	Thru reentry	x			
Yaw Attitude	+ 1/2°	Thru reentry	x			
Pitch Rate	+ 1/2°/sec.	Thru reentry		x		
Roll Rate	+ 1/2°/sec.	Thru reentry		x		
Yaw Rate	+ 1/2°/sec.	Thru reentry		x		
Horizon Sensor, Pitch		Thru reentry		x		
Horizon Sensor Roll		Thru reentry		x		

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Vehicle Gemini

Table 3.3.2-1 (Contd)

System Instru. and Communi.

Information Requirement	Comments on Accuracy	Mission Phase(s)	Category			Remarks
			A	B	C	
5V. Reference	$\pm 1/2\%$ F.S.	All		x	x	
"Ground" Reference	$\pm 1/2\%$ F.S.	All		x	x	
20 mv Reference	$\pm 1/2\%$ F.S.	All		x	x	
Radar Beacon Failure		Thru reentry		x		
Uplink "Telemetry Calibrate" Command		Thru reentry	x			Need calibration control to validate all telemetry



Table 3.3.2-1 (Contd)

Vehicle GeminiSystem Environmental

Information Requirement	Comments on Accuracy	Mission Phase(s)	Category			Remarks
			A	B	C	
Suits 1&2 Pressure	+0.1 PSI	All		x		Must be highly accurate to be significant. Might consider P.P. CO <sub>2</sub> .
Suits 1&2 Temperature	+ 5° C	All		x		
Cabin Pressure	+0.1 PSI	All		x		
Cabin Temperature	+ 5° C	All		x		
Suits 1&2 Humidity	+ 5%	All		x		
Suits 1&2 Partial Pressure O <sub>2</sub>	+ 1% F.S.	Thru reentry		x		Valuable if the Gemini/ Agena combination maneuvers to high orbits
% Primary O <sub>2</sub> Remaining	+ 2%	Thru reentry		x		
% Secondary O <sub>2</sub> Remaining	+ 2%	Thru reentry		x		
Coolant Temperature	None	Thru reentry			x	
#1 Coolant Pump Failure		All		x		
#2 Coolant Pump Failure		All		x		
Compressor Failure		All		x		
Dosimeter Condition		Orbit			x	

3.3.2-9

Table 3.3.2-1 (Contd)

Vehicle GeminiSystem Structures

Information Requirement	Comments on Accuracy	Mission Phase(s)	Category			Remarks
			A	B	C	
Launch Vehicle 1st Stage Sep.		Launch	x	x		(A) Real time verif. (B) Backup command
Launch Vehicle/Spacecraft Sep.		Launch, Reentry	x	x		(A) Real time verif. (B) Backup command
Equipment Section Sep.		Reentry		x		
Retro-Section Sep.		Reentry		x		
Skid Extension		Reentry		x		

Table 3.3.2-1 (Contd)

Vehicle Gemini	Information Requirement	Comments on Accuracy	Mission Phase	Category			Remarks
				A	B	C	
	Main Bus Voltage	$\pm 1V.$	All		x		
	Secondary Bus Voltage	$\pm 1V.$	All		x		
	Main Bus Current	$\pm 0.1 A$	All		x		
	Secondary Bus Current	$\pm 0.1 A$	All		x		
	Squib Battery Condition		All		x		
	H <sub>2</sub> Quantity		All		x		
	H <sub>2</sub> Pressure		All		x		
	O <sub>2</sub> Condition		All		x		
	Fuel Cell #1 Current		All		x		
	Fuel Cell #2 Current		All		x		
	Fuel Cell Coolant Temperature (Avg.)		All		x		

System Power

Table 3.3.2-2  
AGENA INFORMATION REQUIREMENT

Vehicle <u>AGENA</u>		System <u>Guidance</u>				
Information Requirement	Comments on Accuracy	Mission Phase	Category			Remarks
			A	B	C	
Pitch Gyro Output	+ 1/2° + 1/2° + 1/2°  + 1/2°/sec. + 10 FPS	Thru Orbit	x			} Backup for gyro data
Roll Gyro		Thru Orbit	x			
Yaw Gyro Output		Thru Orbit	x			
Pitch Sensor		Thru Orbit		x		
Roll Sensor		Thru Orbit		x		
Pitch Rate		Thru Orbit	x			} Backup for Attitude Readouts
Velocity Sensor		Thru Orbit	x			
Programmer Memory		Thru Orbit	x			
Uplink "Booster Commands"		Thru Orbit	x			
Command Verification		Thru Orbit		x		

Table 3.3.2-2 (Contd)

Vehicle <u>AGENA</u>	Comments on Accuracy	Mission Phase	System Propulsion			Remarks
			A	B	C	
Oxidizer Pump Temperature		Thru Orbit		x	x	
Oxidizer Pump Pressure		Thru Orbit		x	x	
Fuel Pump Temperature		Thru Orbit		x	x	
Fuel Pump Pressure		Thru Orbit		x	x	
Turbine Speed		Thru Orbit		x	x	
Chamber Pressure		Thru Orbit		x	x	
% Oxidizer Remaining	+ 1% -	Thru Orbit	x			} Required for Energy Management
% Fuel Remaining	+ 1% -	Thru Orbit	x			

Table 3.3.2.2-2

Vehicle <u>AGENA</u>		System <u>Power</u>				
Information Requirement	Comments on Accuracy	Mission Phase	Category			Remarks
			A	B	C	
28 V Regulated Supply Voltage	+ <u>0.1 V</u>	Thru Orbit		x		
28 V Bus Voltage	+ <u>0.1 V</u>	Thru Orbit		x		
Inverter Output Voltage	+ <u>1 V</u>	Thru Orbit		x		
Inverter Temp.	+ <u>5°C</u>	Thru Orbit		x	x	

3.3.2-14

### 3.3.3 Life Support Systems General Information Requirements

Information requirements needed for life support monitoring purposes may be divided into the following four functional areas: requirements for monitoring the crew status, requirements for initiating biomedical experiments, requirements for monitoring the spacecraft environment, and requirements for monitoring the environmental control systems. For missions not involving any planned biomedical experimentation, such as the operational rendezvous phase of the Gemini Project, essential crew status information will be monitored within the IMCC. In all missions, the environmental conditions aboard the spacecraft will be monitored by both the astronauts and the IMCC operations personnel. The types of required information should remain essentially constant throughout the entire project, except for the longer orbital flights. Each of the four functional areas of information requirements described above will be discussed in the paragraphs which follow.

3.3.3.1 Crew Status Information Description. Crew status information includes information needed to monitor the health, safety and well-being of the crew. It is assumed that the status of the crew will be monitored for all flights and that monitoring will be done in real time or in nearly real time. Although much physiological and psychological data will be obtained prior to the operational rendezvous phase, crew monitoring should be continued because of the abnormal stress associated with the flight environment and the new operations. Real-time evaluation is required to provide awareness of impending crew failure which could lead to termination of a mission.

An advantage in the Gemini flights as far as crew observation is concerned is that the two astronauts can observe each other. These subjective observations transmitted by voice, are perhaps as important as the instrumented monitoring information telemetered to the ground stations.

Table 3.3.3-1 shows the information requirements needed for adequate crew monitoring of each astronaut during all phases of any mission. The listed parameters are the minimum needed to assess the condition of the astronauts and to perform gross diagnoses of any disorders but are considered sufficient. (It is assumed that even mild symptoms of a possible disorder may be enough to terminate a mission and hence no further diagnosis would be necessary.) Each of these items, a description of its function, and general requirements for accuracies of readout indications are discussed in the following paragraphs. Also indicated are the sampling rates as they were obtained from NASA personnel.

- a. Respiration rate and volume. Measurement of this parameter gives an indication of the astronaut's overall physical condition, and also indicates that the oxygen volume and partial pressure are indeed sufficient and that the carbon dioxide partial pressure is low enough to support life. This item should be monitored continuously throughout the mission. The accuracy of the transducer and of the associated telemetry links and display system should be such that the resulting readout closely approximates both the respiration rate and the tidal volume of air. The sampling rate will be 160 samples per second.
- b. Skin Temperature. This parameter is also an indicator of the astronaut's general physical condition. During checkout and launch, this item, along with the rest of the aeromedical data, will be monitored to indicate any disorders in the crew which would require a mission scrub. Skin temperature is also required periodically throughout the orbital (and rendezvous) phases to monitor any deviations from the normal temperature range, which would be grounds for a mission termination. Overall accuracy must be sufficient to allow temperature readout to within one-tenth of a degree. Sampling will be done at the lowest available sampling rate of 1.25 samples per second.
- c. Blood pressure. Blood pressure measurements will be taken to determine the condition of the circulatory system. This measurement will be taken in the checkout and launch phase to determine whether any symptoms exist which would cause a mission scrub. During the orbital (and rendezvous) phases, blood pressure will be monitored periodically to aid in evaluating the astronaut's general condition. Accuracy of the system must be sufficient to yield a readout within one



Table 3.3.3-1

## CREW STATUS MONITORING INFORMATION REQUIREMENTS

	Flight Phase					
	Checkout and Launch	Powered Flight	Orbit (and Rendezvous)	Reentry* and Descent	Descent with Lift	Recovery
Respiration Rate and Volume	x	x	x	x	x	x
Skin Temperature	x		†			
Blood Pressure	x		†			
EKG**	x	x	x	x	x	x
Pulse Rate	x	x	x	x	x	x
Voice	x	x	x	x	x	x
Observation by Other Astronaut	x	x	x	x	x	x

\* Information not available during portion of reentry unless state-of-the-art advances sufficiently

\*\* EKG not monitored after orbit (and rendezvous); needed, however, to derive pulse rate

† Readout on demand or by command

millimeter of mercury of that measured by the transducers and to provide an indication of the presence of the Korotkoff sounds. Sampling will be done at a 400 sample per second rate.

- d. Electrocardiogram (EKG.) The electrocardiogram readout allows a refined evaluation of the astronaut's heart condition. In addition to the derivation of the pulse rate, the electrocardiogram yields information which aids in the diagnosis of any heart arrhythmias. During checkout and launch, the EKG will be monitored to indicate any disorders that would require a mission scrub. The EKG will also be monitored during the powered flight, orbit (and rendezvous,) and retrofire and reentry phases to assess the effects of the stresses associated with the flight. No EKG monitoring would be required for the remaining phases of the flight. The fidelity of the EKG transducer, and the bandwidth and S/N ratio of the telemetry channel must be sufficient to allow a display of all the major components of the EKG waveform. The sampling rate will be 480 samples per second.
- e. Pulse rate. Pulse rate is derived from the EKG data and yields a measure of the astronaut's general condition. It should be monitored during the entire mission.
- f. Voice. Direct communication with the astronaut yields valuable medical information. In addition to monitoring the astronaut's own interpretation of his own health and well being, ground personnel will evaluate his voice to obtain an independent estimate. To ensure adequate voice quality, a bandwidth of at least 3 kc, (preferably higher) should be used for voice communication.
- g. Observation by other astronaut. Observation of the subject by the second crew member will aid in the medical evaluation of the astronaut. Facial expressions, color observation, and general physical and elementary psychological descriptions can be obtained from this observer.

The range of voltage values required for the first four parameters listed above is 0 to 20 millivolts. All of the parameters will be monitored in real time.

3.3.3.2 Biomedical Experiments Information Description. It is beyond the scope of this report to describe all of the requirements for biomedical experiments. Many factors, such as the space available aboard the spacecraft and the number of available telemetry channels, will

determine the final mission medical packages. It is assumed that most medical information, required for research purposes, will be obtained during the fourteen-day missions. Emphasis on determining a biomedical baseline for the space environment in the Gemini Project should preclude the need for an expansive series of biomedical experiments for the Apollo Project. It is assumed that NASA will develop the final biomedical test plan.

According to information from a NASA source, current plans call for adding three types of sensors to accomplish biomedical experimentation. These sensors will yield the capability for obtaining phonocardiograms, electroencephalographs (EEG) and the galvanic skin response (GSR.) The phonocardiogram sensor will have a sampling rate of 960 samples per second; the EEG sensor will have a sampling rate of 960 samples per second; and the GSR sensor, 80 samples per second. All of these parameters will have a range of 0-20 millivolts.

In addition to obtaining data from these sensors for experimental purposes, the crew monitoring sensors will be used as investigative tools for experiments involving reaction to the space environment for extended periods of time.

Most of the data from medical missions would not have to be analyzed in real time. Exceptions would be data which the Flight Surgeon requires to determine the following phases of an experiment.

As the Gemini Project enters the operational rendezvous phase, very little medical instrumentation should be added to that necessary for monitoring crew status, except for experiments which are conducted to verify or expand existing data.

3.3.3.3 Environmental Monitoring Information Requirements. Adequate information must be telemetered from the spacecraft concerning the condition of the on-board environment. The environment must be monitored to ensure that no hazard exists or can be predicted that will incapacitate the crew or cause it to operate at any efficiency less than that which has been planned. Information presented to the environmental monitors will consist of real-time information, trends, and historical information. The required real-time information and its associated accuracy, has been listed by the spacecraft contractor and is considered adequate. However, it is recommended that all of the environment measures be transmitted for all phases of the Gemini Project. Although some of these parameters will be presented within the cabin, it is felt that dependence should not be made on the voice links only for this data during the operational phase, especially data from which trends will be obtained. Present plans call for telemetering the following items:

- a. Cabin oxygen partial pressure
- b. Cabin pressure
- c. Cabin temperature
- d. Suit pressures
- e. Suit inlet air temperature
- f. Secondary oxygen rate valve open-closed
- g. Cabin carbon dioxide partial pressure
- h. Suit carbon dioxide partial pressure
- i. Acceleration
- j. Radiation dosimetry

Acceleration measures should be taken so that correlation can be obtained between physiological events and this aspect of the environment. Radiation measurement, although not foreseen as being critical, will yield a radiation baseline at the orbital altitudes as well as warning of any potential radiation danger.

Processing and use of these data and other types of information needed at the IMCC are discussed in subsequent sections.

3.3.3.4 Environmental Control Systems Monitoring Information Requirements. The elements of the environmental control system (ECS) will remain essentially the same for most Gemini missions as for Mercury. It is not known whether the problems unique to the longer missions, such as the incorporation of a body waste disposal system and the possible use of a regenerative ecological system will alter information requirements for ECS monitoring. So that the ground support system may function effectively, it is recommended that the present method of telemetering information from transducers, which also drive displays for the crew members, be continued. Information should also be telemetered which will aid the flight controllers to evaluate the seriousness of a system malfunction; that is, more than subsystem "Go, No-Go" information should be telemetered. It is assumed, however, that telemetry used to evaluate particular pieces of equipment as they are developed will be discontinued as the program advances. It is assumed that the Gemini vehicles, for extensive orbital missions, may serve as test beds for technique and component evaluation for life support and environment controls to be used in the Apollo Project. If so, those will require more telemetry capability than that needed for normal operational Gemini missions. Verbal reports indicating the status of foodstore and water for the longer missions are considered sufficient. The spacecraft contractor has developed a list of the ECS monitoring parameters which will be telemetered. From this list, the following items are considered minimal for monitoring purposes.

- a. Oxygen primary tank pressure
- b. Radiator outlet temperatures for the ECS, fuel cell and electrical cooling system
- c. Primary oxygen supply temperature
- d. Mass quantity of the oxygen primary supply.

It is not known at this writing if the number of ECS telemetered data can be safely reduced to the above items. Only experience with the ECS will indicate the exact amount of information needed for monitoring purposes.

The use of this data and its processing are discussed in other sections of this report.

### 3.3.4 Network Communication and Tracking

#### 3.3.4.1 General.

- a. GOSS Communication System Makeup. This section discusses the types of information needed to maintain adequate status-awareness and to control the GOSS communication network. Regardless of the final configuration of the network, it is convenient to depict it as a set of six areas containing major groupings of equipments:
  1. Integrated Mission Control Center (IMCC)
  2. Remote sites
  3. Point-to-point links
  4. Spacecrafts
  5. Launch control complex
  6. Recovery control complex
- b. General Requirements. To prepare, coordinate and maintain this network in a state of mission readiness, there must be an awareness at the IMCC of the status of these six equipment groupings. To insure that proper decisions are made and adequate actions are taken to maintain network readiness and communication discipline, many items of information must be gathered and either displayed (directly or in combination) or made available for call-up. Although it is quite likely that many items will never be used unless failures or degradations occur, provisions must be made to acquire this information beforehand in the event that remedial action is necessary. Also, certain communication facts will be needed for moment-to-moment planning and coordination with mission operational procedures. An example would be the case of IMCC maintaining continuous contact with orbiting Gemini spacecraft during rendezvous and docking sequences, where tight control over communication would be essential.
- c. Approach and Intent. It is most appropriate to approach the task of cataloging information requirements from the point of view of the information center, the IMCC. It is true, however, that the spacecraft and other GOSS elements will require specific information available only at the IMCC. The manner in which this information will be supplied to them will be discussed in a subsequent report. The intent here is to present an initial listing of the types of communication system elements about which data will be needed and the nature of these data for each type of element. The probable condition for the use of each information item is indicated. Below are brief descriptions of the system groupings and of the data types, followed by a more detailed cross-tabulation indicating conditions for use of the data.

### 3.3.4.2 System Groupings

- a. IMCC. From a network communication standpoint, the IMCC contains a number of vital equipments. These provide link termination, error control, data conversion, and internal information transfer.
- b. Remote Sites. Communication equipments grouped at remote sites are similar to those at IMCC, plus a few additional. In addition to GOSS link terminals and data converters, the remote sites will include tracking radars and space-ground communication terminals.
- c. Point-to-Point Links. Considering all units of the other five facility groupings as "points," communication links between various combinations of these points will exist. Many of the GOSS links will consist of physical facilities, in the form of telephone lines, video cables, submarine cables, and microwave repeater stations. All of the space-ground and space-space links, and some of the GOSS links, will consist of electromagnetic paths between radio transmitters and receivers operating at specific wavelengths.
- d. Spacecraft. As in the ground complex, links terminating aboard the Gemini and Agena spacecraft will constitute an integral of the total GOSS communication system.
- e. Launch Control Complex. The launch control complex will contain terminal equipments and data processing equipment which will form part of the total GOSS communication system. Failure or degradation of these equipments will affect the operation of the GOSS communication system.
- f. Recovery Control Complex. The term Recovery Control Complex includes all recovery units physically separated from the IMCC. Similarly, as indicated in the preceding paragraph, this complex constitutes an element in the total GOSS communication system. However, it uses a separate, military communication network.

3.3.4.3 Required Data. The required items of information can best be described by categorizing them into groups according to the manner in which they describe parameters of the communication system. Four such basic categories of indicators evolve:

1. Status
2. Relative performance
3. Time reference
4. Statistical.

- a. Status. Indications of status will show in which of two or more known states the elements of the system are operating. Normally, these indications are of the on/off, or in/out type. A circuit is in or out of operation; a radar has acquired the spacecraft or not; etc.
- b. Relative Performance. This data is characterized by its relative nature, usually tacitly compared to a standard, so that its indication may show as "high, low, medium, or normal." In a few cases, performance indicators may be direct diagnostic displays, for example, showing the cause for certain events in the network, such as outages.
- c. Time Reference. These data show time-reference indications necessary for management of the communication system. The expected time of spacecraft acquisition by the radar at a given site, for example, or the expected time at which an outage will be restored.
- d. Statistical. These data are predominantly of the type which are gathered for post-mission analysis. Sequentially-recorded indications of status and performance data, however, may also serve to generate statistical data for this purpose. Message counts and quantity of outages, recorded as a function of some unit of time, are examples of statistical data useful both for post-mission analysis and for network planning.

3.3.4.4 Information Uses. Quantitative measures of timeliness and the utilization of data, relative to the communication system elements, will be divided into three categories:

1. For normal operations
2. For contingency operations
3. For post-mission analysis.

Table 3.3.4-1 illustrates the interrelationship between system elements, the data required, and the purpose for which the data will be supplied. In this chart, the items of data are arranged by functional usage, rather than by the categories identified in paragraph 3.3.4.3.



Table 3.3.4-1 Preliminary Requirements for Information Regarding Communications Network

Representative Types of Communication Elements about/for which Information will be Required	Outage										Matrix Entries:		
	In Ready Condition	Priority of Operation	Outage Cause	Expected Restoration Time	In Use (Contact)	Expected Time to Termination	Time Since Initial Use (Contact)	Time of Termination	Message Count	Mode of Error Detection	Timely Conditions for use of Information		
IMCC	Prime/Alternate Designation	Outage	Time of Failure	Expected Restoration Time	In Use (Contact)	Expected Time to Termination	Time Since Initial Use (Contact)	Time of Termination	Message Count	Mode of Error Detection	Timely Conditions for use of Information		
Teletype Terminals	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Hi Speed Data Terminals	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Lo Speed Data Terminals	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Voice Terminals	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Video Terminals	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Video Converters	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Internal Intercom	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Internal Video Com	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Commercial Power	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Standby Power	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Remote Counterparts to IMCC Elements	See above												
Remote Stations Including LCC & RCC	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Telemetry Receiving Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Command Transmitting Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Voice Receiving/Transmitting Syst.	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Antenna Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Radar's (Tracking Systems)	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Links	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Teletype Circuits	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Hi Speed Data Circuits	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Lo Speed Data Circuits	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Voice Circuits	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Video Circuits	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Optical Paths	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Spacecraft	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Telemetry Transmitting Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Command Receiving Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Voice Receiving Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Voice Transmitting Systems	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC
Radar Beacon Transponders	AB	A	AB	ABC	C	AB	AB	AB	C	ABC	C	AC	AC

Matrix Entries:

Timely Conditions for use of Information

A: Normal Mission

B: Contingency Co

C: Post-Mission Analysis

☐: Not Applicable

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### 3.3.5 Operations and Procedures

3.3.5.1 General. Information concerning operations and procedures must flow through the GOSS system and, to a lesser extent, through the space-ground complex as well. It is expected that during live operations, this will be minimal, since advanced planning should have standardized the regulations for each live mission. Initial procedural regulations for each mission will be set in advance and disseminated as a book of mission rules.

Information will be needed to initiate, modify, and up-date these rules. This will require that data on new ideas flow not only within IMCC planning areas but also in from field operational areas. Upon completion of procedures generation or revision, these data must flow back out again to users.

3.3.5.2 Procedures Generation. As staff to the Flight Director, operations and procedures officials will generate the rules for conduct of each mission in the Gemini Project. The input information will come initially from experience gained in the Mercury Project and from the new Gemini mission requirements generated by Gemini planners. For later mission rules, the accumulated Gemini flight experience will be brought to bear on procedures development.

3.3.5.3 Procedures Modification. Operational procedures will undergo a continual revision process. The information required for such modifications will come from observed and recorded feedback from simulations, from dress rehearsals and from preceding missions. Each incident of contingency occurrence, schedule slip-up, broken rules or inefficient operation will serve as an information source for procedures modification.

### 3.3.6 Launch System

3.3.6.1 General. Table 3.3.6-1, "Gemini Information Requirements —Launch System" has been extracted directly from the initial version of WDL-TR-E114. For the sake of completeness within this report, it is expedient to repeat this information, found in Subsection 3.2 of the referenced report.

Table 3.3.6-1 identifies the information requirements, their description, and uses at the IMCC and the LCC to accomplish prelaunch countdown and launch operations. The table is intended to show primarily the division of information requirements between the IMCC and LCC, and to demonstrate the issues involved in this division. This first attempt to list the information requirements is subject to limitations and assumptions, which are discussed below. The requirements are tentative but are considered representative of the information requirements in final form. As the requirements are refined in future iterations, more detailed descriptions supporting them will be obtained.

3.3.6.2 Limitations. The information is grouped according to broad functional information requirements such as downrange systems status, IMCC internal status, etc. Not all such functional requirements are included in this table. Stress has been given to information needed for the IMCC/LCC interface requirements and for most of the IMCC functions for the first three phases of the mission. Information needed for prelaunch operations only, such as fueling and crew insertion, has been minimized. No consideration has been given to the time sequence of these information requirements. Little attempt has been made to segregate the information into areas of physical responsibility within either the LCC or IMCC except in cases in which the responsibility is obvious, such as LCC information requirements and information needed to monitor system status. All of these limitations should disappear as the information flow evolves.

Table 3.3.6-1  
GEMINI INFORMATION REQUIREMENTS  
LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
I Launch Vehicle and Capsule Countdown		
Countdown Sequence	Initiate and monitor checkout sequence. Transmit checkout steps to IMCC.	Inform LCC when final checkout should begin. Monitor checkout steps.
Capsule Systems Status	Monitor results of final checkout tests on all capsule systems. Transmit results to IMCC.	Same as LCC. Determine remedial action in event of contingencies.
Launch Vehicle Systems Status	Monitor results of launch vehicle tests on guidance systems, telemetry system, command system, fueling system, etc. Send status of systems and summary of any discrepancies from programmed tests to IMCC.	Monitor status of systems. Determine remedial action in event of contingencies.
Ground Launch Control System Status	Checkout and monitor all LCC internal systems such as communication nets, local data processing systems, etc., and report status to IMCC. Checkout and monitor LCC portion of LCC-Launch Vehicle Systems such as receiving and transmitting systems, and guidance control systems, and report results to IMCC.	Monitor status of LCC internal systems and LCC portion of LCC - Launch Vehicle Systems. Determine course of action in the event of contingencies.
Crew Status	Physiological and psychological conditions of crew monitored as backup to IMCC.	Physiological and psychological information monitored at IMCC for possible hold or mission scrub.
II LCC - Downrange Systems Status Downrange Stations Status	Monitor the status of systems at all downrange stations, send status and summary of abnormal situations to IMCC.	Monitor downrange systems status. Determine course of action.

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Table 3.3.6-1  
GEMINI INFORMATION REQUIREMENTS  
LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
Data Links Status	Data links between LCC and downrange stations checked out and quality of signals monitored. Summary information on links presented at LCC and transmitted to IMCC.	Monitor overall status of data links. Determine course of action.
Range Communication Net Status	Monitor quality of range communications on nets and periodically issue communication nets checks. Range net status transmitted to the IMCC.	Monitor overall status of communication net. Determine course of action.
III IMCC Internal Status		
Data and Communication System Status		All data and communication transmitting and receiving equipment checked out and status displayed in GOSS system status area.
Data Processing System Status		All data processing equipment including telemetry processors, display data processors, trajectory data processors and computers checked out. Status displayed in GOSS systems status area.
Operational Subsystem Status		All subsystems having primary control and monitor functions at consoles in the FOCR are checked out and their status displayed at appropriate supervisory points.
Communication Net Status		Quality of internal communication nets monitored, comm. checks conducted periodically.
Display and Control System Status		Display and control subsystems including console operation, television system and large scale display checked out and status noted.

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Table 3.3.6-1  
GEMINI INFORMATION REQUIREMENTS  
LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
IV IMCC/LCC Link Status		
Data Links Status	Same as IMCC. Status presented in LCC subsystem status monitor area.	Data links between LCC and IMCC checked out and quality monitored. Summary status presented in GOSS system status monitor area.
Voice Link Status	Link quality monitored	Communication link quality monitored. Periodic comm. checks originated at IMCC. Link status indicated in GOSS system status monitor area.
Television Monitoring System Status	Quality of images transmitted to IMCC monitored.	Quality of link for launch television monitoring observed at IMCC. Malfunction summary presented in GOSS systems status monitoring area.
Capsule - IMCC Links (thru LCC)		
Data Links	Patch Data links at LCC.	Data links from capsule checked out and monitored. Summary status presented in GOSS systems status monitoring area.
Voice Links	Patch voice links at LCC.	Voice links monitored for quality and status indicated in GOSS systems status monitoring area.
Command Links	Patch command links at LCC.	Commands initiated at IMCC and verification observed. Actions as a result of commands relayed by voice from capsule. Status of command system indicated in GOSS systems status monitoring area.

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Table 3.3.6-1

**GEMINI INFORMATION REQUIREMENTS**  
LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
V IMCC - Remote Site Status		
Remote Site Systems Status		State of readiness of remote sites monitored at IMCC GOSS systems status area. Summaries of systems tests and equipment status reviewed.
Data Links Status		Data links between IMCC and remote sites checked out and quality monitored. Status indicated at GOSS systems status area.
Communication Net Status		Quality of communications monitored. Comm. checks initiated periodically.
VI Timing Information		
Systems Time Status	Timing adjustments made as needed. System Time displayed.	Timing synch. generated and transmitted to all systems to coordinate System Time
Time to Liftoff	Time to liftoff displayed.	Estimated time to liftoff computed, displayed at various points locally, and transmitted to LCC.
Countdown Time	Countdown and countdown modification displayed.	Countdown time initiated and modified at IMCC.
Time Since Hold Initiated	LCC recommends holds due to local weather, local equipment malfunction, or planned holds.	IMCC initiates holds, if needed, and Time Since Hold Initiated display. IMCC personnel determine action in event of contingencies.
Estimated Duration of Hold	LCC initiates Estimated Duration of Hold.	Estimated Duration of Hold monitored. IMCC may also initiate if hold originates there.
GMT time	GMT time displayed for reference.	GMT time displayed for reference.

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Table 3.3.6-1  
GEMINI INFORMATION REQUIREMENTS  
LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
VII Weather		
Cape Weather	Weather data furnished at LCC weather center, monitored for potential mission scrub or delay, abstracted and transmitted to IMCC. Launch RCC and launch recovery forces monitor weather reports.	Cape weather monitored at IMCC weather center.
Downrange Weather	Same as above	Same as above
World Weather		World weather furnished at IMCC weather center. IMCC/RCC monitors world weather, transmits projected weather to recovery forces.
VIII Recovery Force Status	LCC/RCC monitors state of readiness of recovery forces. Status transmitted to IMCC.	IMCC/RCC monitors launch and downrange recovery force status.
Launch RCC		
Launch Recovery Forces		
Downrange Recovery Forces		
IMCC/RCC		
Reentry Recovery Forces		IMCC/RCC monitors state of readiness of reentry recovery forces and indicates status to RCC at IMCC.
Reentry Radar Sites Status		IMCC/RCC monitors status of reentry radar sites and initiates checkout of communication and data links. Status of links reported to GOSS system monitoring area.
Reentry Radar Sites Data Link Status		
Reentry Radar Sites Communication Nets Status		

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Table 3.3.6-1

## GEMINI INFORMATION REQUIREMENTS

## LAUNCH SYSTEM

INFORMATION REQUIREMENT	INFORMATION DESCRIPTION AND USES	
	LCC/DOWNRANGE	IMCC
IX Prelaunch Guidance, Acquisition and Tracking Information		
Launch Trajectory Program	Trajectory program transferred to ground guidance data processing equipment.	Trajectory program generated at IMCC and transmitted to LCC.
Downrange Acquisition Data	LCC acts as transfer point for acquisition data.	Acquisition data and acquisition times generated at IMCC and transmitted to downrange stations.
Remote Site Acquisition Data		Acquisition data and acquisition times generated at IMCC and transmitted to remote sites.
X Prelaunch Information for Second Vehicle		
Trajectory Programs	Data transferred to ground guidance equipment and on-board equipment.	Launch azimuth and time, and trajectory modified for second vehicle as tracking information and holds in second vehicle countdown information change requirements.
Acquisition Data	LCC acts as data transfer point for downrange stations.	Updated acquisition data and acquisition times generated at IMCC and transmitted to downrange stations and remote sites.

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3.3.6.3 Assumptions. It has been assumed that all pre-countdown activities have been completed and that a combined flight simulation test has been performed to check out the operation of both launch vehicles and both spacecraft. Functions requiring continuous check-out and monitoring of status through launch are indicated in the table. The IMCC is assumed to have full responsibility for the launch control with the LCC providing the actual launch operation. Either the LCC or the IMCC may authorize an abort, but the physical action of aborting a mission rests with the crew themselves. It is further assumed that most computational equipment, in excess of that needed for immediate control of guidance and impact prediction in the powered flight phase, are located at the IMCC, and that the LCC will contain a central data terminal and data monitoring point through which data and voice communication will be routed to link the IMCC and LCC, the IMCC and AMR downrange stations, and the LCC and AMR downrange stations.

### 3.3.7 Recovery System

Information requirements for recovery are listed in two categories:

(1) information generated by the IMCC and/or other GOSS elements for routing to the recovery forces and (2) information generated by the recovery forces for routing to the RCC (located within the IMCC building) and then to the Flight Director and other MOCR personnel who may need the data. The information is further categorized in terms of time, accuracy constraints and their application, and in terms of the mission phase during which the information is gathered and routed. In addition, where possible, the prime information source and the final destination within the IMCC or recovery organization are indicated, and the required response is listed.

The listing of information requirements is preceded by a discussion of assumptions and definitions.

3.3.7.2 System Assumptions. There are only two types of recovery operations, planned and unplanned, and two corresponding types of recovery areas, planned and contingency.

- a. Planned Recovery. Planned recovery areas are provided for: (1) pad aborts and powered flight aborts at altitudes < 20,000 feet, (2) powered flight aborts at altitudes > 20,000 feet, (3) preplanned deferred emergency landing from any orbit, and (4) landing at mission termination.
  1. Pad Abort, Powered Flight Abort from Altitudes Below 20,000 Feet. The astronauts will be ejected from the spacecraft in ejection seats; positioning of recovery units will be based on ejection seat characteristics and booster staging during early flight. The crew can be located visually.
  2. Powered Flight Abort Above 20,000 Feet. Recovery forces will be located at the most probable landing locations, determined from booster characteristics and likelihood of malfunctions during powered flight. Impact point may be determined visually, from radar tracking, information from Cape Canaveral, including the G E/ Burroughs tracking and guidance facility and/or from impact point estimate received from IMCC. Local radar tracking by recovery forces and down-range stations may be more accurate than impact points estimated by the IMCC. Recovery locations may extend as far as the Canary Islands, depending on characteristics of Titan booster.

3. Deferred Emergency Landings From Any Orbit. Recovery forces will be located to provide capability to accommodate a daylight landing from any orbit. For reasons of economy, it will be necessary that some of these locations cover several orbits. These predesignated landing areas are provided to handle emergencies which do not require immediate or "short term" reentry. It is assumed that reentry can be delayed for most emergencies, so that landing will occur in one of these predesignated areas and that actual time of retrofire, number of retrorockets that fired, and capsule attitude at firing will be available to at least one GOSS station from spacecraft telemetry, voice reports, or both. These are to be planned landings, with landing location selected in advance. However, the actual reentry parameters will be routed to the IMCC where an estimated impact point will be computed and routed to appropriate recovery forces via the RCC in the IMCC. Search will be concentrated in a dispersion area defined by computer prediction.
4. Landing at Mission Termination. The initiation of the retrosequence will be scheduled so that landing will occur at or near the predesignated landing area. Computed impact point will be routed to recovery unit(s) and search will be concentrated in a dispersion area centered about the estimated impact point.
- b. Contingency Recovery. For deferred emergencies, it is assumed that reentry can and will be delayed until the capsule can be landed in one of the predesignated landing areas. Emergencies requiring immediate or short term reentry are assumed to be minimal in number and are designated contingencies. Immediate contingency reentry, by its very nature, is indeterminate, and can occur at any point along the orbital ground track, although the crew may be able to delay reentry sufficiently to land in a preferred contingency landing area (short term). The low probability of contingency reentry and its location indeterminacy imply that planning for contingency recovery should involve no prior deployment of retrieval units. Since advance deployment appears impractical, retrieval units must be deployed after landing. However, contingency search and location units will be deployed prior to the mission in locations which assure extensive coverage of the ground track, considering the effective range of the on-board HF/DF equipment and other location aids.

Throughout the flight, the crew will be continually provided with retrofire times for landing in deferred emergency recovery areas, but the contingency search units shall be capable of flying to any point along the orbital track, not covered by planned landing areas. These contingency units shall have pararescue personnel equipped to provide assistance both on land and water.

### 3.3.7.3 Information Generated Prior to the Mission

- a. Mission Rules, Mission Objectives. Orbital ground track, distance travelled subsequent to retrofire, the planned recovery area for mission termination, areas planned for deferred emergency recovery (each orbit), and contingency recovery areas will be covered by mission rules disseminated prior to the flight. Location and retrieval forces will be deployed to all planned landing areas, and search and rescue units will be located in contingency areas. The latter will not have retrieval capability, but will have electronic location aids such that there is complete coverage of the orbital ground track. These contingency location and rescue units will be capable of flying to any point on the ground track with para-rescue personnel to render assistance.
  1. Mission Phase. Prior to mission
  2. Source of Information. Manned Spacecraft Center (Houston) with IMCC updating, if required
  3. Primary Sources. Mission objectives, flight plan, orbital ground track, booster staging
  4. Destination. GOSS in general, planned recovery forces, contingency search and rescue units, other SAR units as appropriate (may not be desirable to disseminate orbital parameters to world-wide SAR units)
  5. Time and Accuracy Constraints. Not established in detail. Sufficiently in advance of mission with enough accuracy to permit deployment of planned recovery forces and contingency search and rescue units.
  6. Response. Deployment of recovery forces to planned landing areas, deployment of contingency SAR units to give adequate location coverage and rescue capability.
- b. Recovery and Rescue Force Deployment Information. Planned recovery area readiness; area coverage, status of ship and aircraft mobility. Contingency area readiness; disposition of aircraft and/or ships, status of pararescue teams, mobility, area coverage in preferred and secondary contingency areas:
  1. Mission Phase. Prior to mission and updated when changes occur
  2. Source. RCC within IMCC
  3. Primary Sources. Recovery forces at planned recovery areas, contingency SAR units on station
  4. Destination. IMCC Operations Director, Flight Director
  5. Time and Accuracy Constraints. Not specifically applicable. Units report status when fully deployed, prior to launch; update as changes occur

6. Response. If all other aspects are "go," the mission may proceed.

#### 3.3.7.4 Information Generated During the Mission

- a. Time to Retrofire and Retrofire Time (Normal Mission Termination)
  1. Mission Phase. Established tentatively prior to launch on the basis of nominal orbital parameters, continuously updated as mission progresses, using actual orbital parameters
  2. Information Sources. IMCC computing facilities
  3. Primary Sources. Radar tracking data from GOSS network, length of ground track from retrorocket firing to landing for planned landing mode. (This distance must be known to establish time for retrofire and location of landing area).
  4. Destination. Spacecraft, all GOSS network stations
  5. Time and Accuracy Constraints. Continuously updated prior to actual retrofire, accuracy sufficient to land within planned landing area
  6. Response. Spacecraft crew resets retrofire timing clock as required, may manually initiate retrosequence at time zero.
- b. Retrofire Times for Deferred Emergency Landings in Planned Landing Areas
  1. Mission Phase. Established tentatively prior to launch, updated during flight
  2. Source. IMCC computer
  3. Primary Sources. Radar tracking, reentry ground track length including glide phase, location of desired landing areas for each orbit
  4. Destination. Spacecraft crew (retrofire time for landing from current orbit transmitted and updated by voice), GOSS stations
  5. Time and Accuracy Constraints. Current orbit retrofire time must be established as early as possible during each orbit with sufficient accuracy to land within desired area
  6. Response. Spacecraft crew records updated retrofire times; may manually initiate if landing is required.
- c. Retrofire Times for Contingency Landings
  1. Mission Phase. Established tentatively prior to launch, updated during flight. Crew is continuously informed of retrofire times for favorable contingency landing areas

2. Source. IMCC computers
3. Primary Sources. Location of contingency landing area, reentry ground track length, radar tracking
4. Destination. Spacecraft crew (voice transmission), GOSS network stations
5. Time and Accuracy Constraints. See mission phase; also retrofire times for contingency landings may be updated at crew request
6. Response. Crew records retrofire times, may manually initiate if contingency landing necessary.

d. Retrorockets Fired

1. Retrorockets fired: time, number, vehicle attitude (mission termination)
2. Retrorockets fired: time, number, vehicle attitude (deferred emergency landing in planned landing area)
3. Retrorockets fired: time, number, vehicle attitude (contingency landing).

These are the three different conditions for actual times that retrorockets fired, transmitted from spacecraft to ground stations by telemetry, voice or both.

1. Mission Phase. Any reentry from orbit
2. Source. GOSS T/M and voice receiving stations
3. Primary Source. Spacecraft T/M, voice or both
4. Destination. IMCC via tracking stations
5. Time and Accuracy Constraints. T/M indication of retrofiring must occur within range of tracking stations to be effective. Voice reports may be made prior to and after retrofiring. Accuracy of timing will, in part, determine accuracy of impact point estimate to be computed at IMCC.
6. Response. GOSS station(s) transmits retrofire parameters to IMCC. Data input to IMCC computers (with other information) used to compute estimated impact point for transmission to recovery forces and/or SAR units, and to the vehicle.

e. Estimated Impact Point, Time and Dispersion Area

1. Mission Phase. Reentry and landing, mission termination, emergency landing, contingency landing
2. Source. Estimated impact point, impact time and dispersion area are computed by IMCC computers
3. Primary Sources. Retrofire time, number of rockets fired, vehicle attitude, orbital parameters, length of

ground track subsequent to retrofire. Retrofire parameters (time, number, attitude) from vehicle telemetry or voice via tracking stations(s), orbital parameters from prior radar tracking. Possible radar tracking during reentry and glide

4. Destination. Recovery forces, contingency SAR units
5. Time and Accuracy Constraints. If retrosequence is initiated within telemetry range of GOSS station, or if retrofire parameters are transmitted accurately prior to or after initiation, accuracy of estimate and dispersion depend upon uncertainty in reentry path and glide, rather than uncertainty in retrofire parameters. For these conditions, the probable dispersion about the estimated impact point can be estimated. If retrofire parameters are only approximately known, the dispersion will be greater. This is highly unlikely, however, and would occur only for the most unfavorable and least probable contingency landing situations.
6. Response. Estimated impact point, impact time and probable dispersion routed from IMCC (RCC) to recovery forces. If contingency landing, routed to contingency SAR units, also. Appropriate search and retrieval units may commence search, recovery, or rescue operations, as appropriate.

### 3.3.7.5 Miscellaneous Information Required from Recovery Forces

- a. Recovery Force Rotation Plans. For longer missions, it may be necessary to rotate recovery forces for refueling, repositioning, etc.
  1. Mission Phase. Planned prior to mission, actual rotation operations to be conducted so that full-time recovery capability exists. IMCC (RCC) to be informed of changes
  2. Source. Pre-mission recovery logistics planning and recovery force communication with RCC
  3. Destination. Will be interactions between recovery area commanders and between IMCC (RCC) and recovery area commanders, to insure full-time recovery capability during actual rotation of vehicles and personnel
  4. Time and Accuracy Constraints. Not applicable, if rotation sequenced properly
  5. Response. See Mission Phase above.
- b. Recovery Force Mobility. If there are significant changes in location and retrieval capability due to rotation of vehicles and/or personnel, or loss of mobility due to malfunctioning ships or aircraft, the IMCC (RCC) must be informed so that replacement or redeployment can be started.

3.3.7-6



- c. Spacecraft Contact, Location, Crew Status, Assistance, Recovery Progress, Spacecraft Status, Return Plans and Progress
  - 1. Mission Phase. Immediately prior to landing and/or when contact first established, through actual retrieval
  - 2. Source. Recovery units most directly involved
  - 3. Destination. IMCC (RCC)
  - 4. Time and Accuracy Constraints. Not applicable
  - 5. Response. Generally, for information only.

#### 3.3.7.6 Miscellaneous Information Required by Recovery Forces

- a. Acquisition Data, Radar

Mission Phase. Known, generally, prior to mission, updated as required during flight, final acquisition data for reentry and glide transmitted from IMCC to recovery forces via RCC.
- b. Descent Mode. Planned prior to flight, recovery forces informed of changes and their implications for recovery operations.
- c. Crew Status, Vehicle Status, Communications, Mission Progress. Recovery forces are continually informed of mission progress. All information pertinent to recovery (i. e., location aids, expected crew status and vehicle conditions on landing) will be transmitted through the RCC.

### 3.4 CONSTRAINTS ON INFORMATION FLOW

In the analyses leading to an information flow plan, it is insufficient to consider only information flow requirements without considering the constraints on this flow. All the characteristics of the information flow must be examined along with the flow itself. A tentative list of the most important characteristics (from a design and/or decision standpoint) are:

- a. Timeliness. How long after it is requested is information supplied?
- b. Accuracy. How realistic is the supplied information?
- c. Reliability. How much faith should the operator place on this information requirement?
- d. Security. Is the information requirement authorized or covert?

In its present form, this section offers no formal analysis of constraints; this will be part of subsequent revisions. One should note, however, that this report is not devoid of a consideration of constraints on information flow. Paragraph 3.3.2, for example, reveals a relatively detailed presentation of accuracy constraints on vehicle-systems information. Throughout this report, similar examples appear but it is and will be the purpose of this section to consolidate the analysis leading to such examples.

## SECTION 4

### ACCOMMODATION OF REQUIREMENTS

#### 4.1 SOURCE ANALYSIS

It is recognized that this report contains information beyond the scope of information flow. In some instances, this report presents information which is properly a part of the performance requirement specification, but is included in this report for the reasons indicated below. These data will be deleted from this report and included into the appropriate reports on performance specification at the time of submission.

- a. The time constraints on the Philco studies and the heterogeneity of available information have resulted in more effort being placed on certain aspects than others, not always in logical order. The non-availability of information has made it necessary to spend time developing information in areas of information voids for completeness.
- b. Realistically, it is recognized that certain existing equipments and instrumentation will constrain the information flow. Consequently, references to such situations are made in this report.
- c. The parallel design effort of the Gemini spacecraft by McDonnell overlays a set of constraints on information sources. Recognition of these facts is presented in this report.

The information requirements derived in the previous section imply that an accommodating source will be supplied. However, for reasons of project urgency, the generation of requirements and

sources are to some extent paralleled procedures. The current study involves two parallel efforts on a limited time scale: the generation of information flow requirements and information flow plans, and the generation of GOSS performance requirements specifications. The parallel nature of these two efforts makes it necessary to make preliminary assumptions about the types of functional subsystems which may be used without waiting for more definitive analyses of operational and technical requirements. It should be understood that such assumptions are made for current working purposes and do not imply adoptions or recommendations of specific functional equipments.

In view of the above, mismatches between requirements and sources may occur. A general objective of the analysis will consist of determining the degree that these initially assumed sources satisfy the information requirements. This is particularly applicable to the vehicle instrumentation where the design has been nearly finalized by McDonnell Aircraft and NASA for the Gemini program.

#### 4.1.1 Vehicle Instrumentation Analysis

The prime goal of instrumentation analysis herein will be to provide a means of evaluating the adequacy of currently planned spacecraft instrumentation. As might be expected, this is an iterative process to be applied between the evaluation of information requirements and instrumentation designs. The continuing objective will be to give indications of validation of equipment design, modifications, additions or deletions.

#### 4.1.2 Measures of Equipment Adequacy

Various measures will be applied to instrumentation parameters to ascertain adequacy. A listing of these measures includes:

- a. Relative priority
- b. Accuracy
- c. Power
- d. Weight
- e. Space
- f. Bandwidth
- g. Reliability factors.

Relative priority will be inferred under three categories of information; namely, Critical to Missions, Contingency Backups, and Engineering Analysis. These will be defined later.

Accuracy will be presented as that required of the particular parameter, and will later be expanded to include equipment capability. The next three measures, power, weight and space are parameter penalties, and each adds up to a definite limiting value and thus becomes important in trade-off considerations. Bandwidth requirements will be presented when loading by mission phase is fully determined so as to accommodate the "worst case" conditions. Reliability will consider such factors as interdependence of parameters, redundancy or alternate information flow paths, and the influence of classes of components ( diodes, relays, limit switches, etc.) on reliability of particular equipments. These measures of adequacy will be treated as more instrumentation data becomes available.

A further objective of the instrumentation analysis will be to determine suitability of equipment for generating the required information. This will be focused primarily on two aspects. One will concern equipment and system over-sophistication and the other will attempt to monitor whether the instrumentation is optimum state-of-the-art.

#### 4.1.3 Tabular Analysis of Information Sources

The Gemini information data is presented in Table 4.1.3-1 in a form parallel to that currently in use.<sup>1</sup> This format should facilitate coordination on vehicle equipment discussions. However, the format will evolve as more measures of adequacy are applied.

The headings in Table 4.1.3-1 labeled **Mission Essential**, **Contingency Backup** and **Engineering Analysis** are defined as follows:

- a. Mission Essential. This category is comprised of information transmission which requires processing or decision beyond the capability of the vehicle. Most often this category of information is found in ground/spacecraft real-time command/control loops. Certain orbital control and adjustments, primary timing and calibrations are examples of this category of information.
- b. Contingency Backups. Information flow from sensors which monitor all essential spacecraft subsystems falls in this category. On the ground, this information will be filtered for negative behavior (system performance outside specified limits) and processed to determine the corrective course of action.
- c. Engineering Analysis. This class of information results from specialized experiments, data for publicity purposes and information of value to analysis in the event of catastrophe. This category has a lower priority than the other two, yet where it is required for unforeseen contingency analysis, must also be available in the same time reference as Contingency Backup, above.

Other headings in Table 4.1.3-1 are believed to be self-explanatory, except that it should be noted that items checked under **Mission Phase** indicates that transmission to or from GOSS is taking place during that phase.

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1. McDonnell Aircraft, Instrumentation Subsystem Summary Table dated 16 May 1962.

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS  
Sequencing System

Sequencing System		Generating Instrumentation	Data Characteristics	Sample Rate per sec.	Phase											Remarks
Parameter	Purpose of Information				Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Checkout	Launch	Pow. Flight	Orbital	Re-entry	Descent	Recovery	
Time Since lift off	Time correlation of events since lift off.	Programmed clock	Digital Readout	10	NA	x	x	x	x	x	x	x	x			
Time to TR	Time reference for astronaut and recovery units.	Programmed clock	Digital Readout	1.25	NA	x	x	x	x	x	x					
Time to TC	Time reference for astronaut and recovery units.	Programmed clock	Digital Readout	1.25	NA	x	x	x	x	x	x	x				
Time since retro fire	Time reference for astronaut and recovery units	Programmed clock	Digital Readout	1.25	NA	x	x					x	x	x		
Launch																
Failure to Stage	Indication of proper booster operation.	28 V. d. c. signal	Bilevel	10	.1s	x	x	x	x						A failure in any of these would set in motion contingency operations which might lead to a termination of the mission.	
2nd Stage Cutoff	Indication of proper sequencing.	Limit Switch	Bilevel	10	.1s	x	x	x	x							
Launch Vehicle and S. C. Sep.	In case of improper or failure to separate this will show if pwr. was applied to shaped charge.	Relay Closure	Bilevel	10	.1s	x	x	x	x							
Spacecraft shaped charge fired																
Orbit & Rendezvous																
Dock. Mech. engaged.	Indication of proper functioning of docking mechanism.	Limit Switch	Bilevel	10	.1s	x	x				x				Failure of S.C. and Agena to discharge would require emergency sep. charge to be fired.	
Dock. Mech. released.																
S. C. Agena Connector retracted																
Emer. Dock. Sep. charge fired.	Indication of pwr application to emergency shaped charge		Bilevel	10	.1s	x	x				x					
Retrograde																
Adapter shaped charge fire.	Indication of pwr application to adapter shaped charge	Relay Closure	Bilevel	10	.1s	x	x									
Equip. Section Sep.	Ind. of proper separation	Limit Switch	Bilevel	10	.1s	x	x				x				A failure of any of these would set in motion contingency operations which might lead to the termination of the mission.	
Retro Rockets Fire Initiation	Indication of proper Rocket Ignition	28 V. d. c.	Bilevel	10	.1s	x	x					x				
Retro Section Jet-son	Indication of proper separation.	Limit Switch	Bilevel	10	.1s	x	x					x				
Retro Sect. Shaped Charge Fire	Indicate application of power to shaped charge.	Relay Closure	Bilevel	10	.1s	x	x						x			

4.1.3-2

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS																
Sequencing System			Generating Instrumentation	Data Characteristics	Sample Rate	Phase								Remarks		
Parameter	Purpose of Information					Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Checkout	Launch	Post. Flight	Orbital		Retro	Re-entry
Landing Dock. & Reent. Jettison	Indication of proper jettison action	Limit Switch	Bilevel	10	.1s		x	x								A failure in any one of these will force contingency decisions as to how best to bring the spacecraft down to a safe landing and/or whether possibly vehicle abort and astronaut ejection should take place.
Drogue Chute Deploy	Indication of proper chute deployment	Limit Switch	Bilevel	10	.1s		x	x							x	
Nose Gear Pos.	Indication of position status of landing gear.						x	x								
Right Main Gear Position.							x	x							x	
Left Main Gear Position																
Paraglider Inflation Cable Rel.	Indication of available pressure.	Pressure Xducer		1.25	2%		x	x							x	These are all indications of status of emergency operations initiated by a previous failure which may in turn require further contingency operations to take place.
Forward Paraglider Cable Release	Indication of whether or not cable release has occurred.		Bilevel	10	.1s		x	x							x	
Abort Abort Relay No. 1 and/or No. 2	Indication of decision to abort by one or both astronauts.		Bilevel	10	.1s		x	x							x	
Ejection Seat Mode (Man. or Auto. 1)	Ind. of who has control or ejection initiation.															
R. Eject. Seat Initiative	Indication of astronaut ejection															
L. Eject. Seat Initiative																
Emer. Retro Fire Salvo Relay	Indication of firing of emer. retro. salvo.		Bilevel	10	.1s		x	x						x		
Jettison Fwd. Paraglider Cable	To ind. the jettisoning of the fwd. paraglider cable		Bilevel	10	.1s		x	x							x	



Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase										Remarks
					Accuracy	Mission Essen.	Contingency Backup	Launch	Post Flight	Orbital	Retro	Re-entry	Descent	Recovery	
Reactant Storage (F.C.)	Supply Information as to how much fuel for the fuel cells is still available thus enabling a decision on remaining fuel cell life to be made.	Pressure Xducer	0 to 100%, 20 %/sec	1.25	2%	x	x	x	x	x					Should fuel cell reactants run out before the expected mission completion the mission, due to lack of electrical pwr, will have to terminate.
Oxygen: Quantity			0 to 100psia, 20 %/sec			x	x	x	x	x					
Hydrogen: Quantity			0 to 100%, 20 %/sec			x	x	x	x	x					
Pressure			0 to 500psia, 100psi/sec			x	x	x	x	x					
Oxygen Condition (F.C.)	Supply information regarding operation of the Fuel Cells.	Pressure Xducer	0 to 20 psia, 4psi/sec	1.25	1%										An indicated failure here, depending on its severity might cause a termination of the mission.
Reg. Press: Sect. 1			0 to 20 psia, 4psi/sec												
Sect. 2															
Press } Sect. 1			off @ 1.5 ± .5 PSID	10	.1s	x	x	x	x	x					
O <sub>2</sub> to H <sub>2</sub> O } Sect. 2			off @ 1.5 ± .5 PSID												
Temp. at H.X. Outlet		Temp. Sensor	50 to 150° F, .5°/sec	1.25	2%										Duplicate sets of signals are required, one from section 1 and one from section 2.
Hydrogen Cond. (F.C.)															
Press } Sect. 1			off @ .36 ± .18 PSID	10	.1s										
H <sub>2</sub> to O <sub>2</sub> } Sect. 2			off @ .36 ± .18 PSID												
Temp. at H.X. Outlet			50 to 150° F, .5°/sec	1.25	2%										Should an indication of improper operation of the Purge system occur the astronaut will be required to assume manual control.
Sect. 1 and 2 Conditions (F.C.)															
B.C.I. Reference															
Stack A - BCI															
Stack B - BCI															Excessive temperature readings should alert the crew to monitor loading indicators.
Stack C - BCI															
Purge	Provides indication of cleansing system status.		bilevel	10	.1s										
Temperatures															
Battery Condition	This serves to detect any excessive loading on the battery.		0 to 200° F, 1°/sec	1.25	5%	x	x	x	x	x					
Temp. Battery No. 1															
Battery No. 5															
Squib Battery No. 1															

Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

Electrical Power Subsystems		Generating Instrumentation	Data Characteristics	Phase										Remarks		
Parameter	Purpose of Information			Sample Rate	Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Checkout	Launch	Post Flight	Orbital	Retro		Re-entry	Descent
Bus Voltages Main Bus No. 1	Provide an indication of supply voltages and load currents.		15 to 35 Vdc, 5V/sec	1.25	2%	x	x	x	x	x						An improper indication will as a minimum require counter checks - in the worst case should the readings prove to be true the mission may be prematurely terminated.
Main Bus No. 2			15 to 35 Vdc, 5V/sec													
Squib Bus No. 1(Arm)			15 to 35 Vdc, 5V/sec													
Squib Bus No. 2(Arm)			15 to 35 Vdc, 5V/sec													
Bus Currents Main Bus No. 1			0 to 50 amps, 30A/sec	1.25	2%	x	x	x	x	x	x					
Main Bus No. 2			0 to 50 amps, 30A/sec													

An improper indication will as a minimum require counter checks - in the worst case should the readings prove to be true the mission may be prematurely terminated.

Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

Environmental Control System			Generating Instrumentation	Data Characteristics	Sample Rate	Phase										Remarks
Parameter	Purpose of Information					Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Launch	Orbital Flight	Retro	Re-entry	Descent	Recovery	
Oxygen Storage Prim. } Mass Quan. Sys. } Tank Press. Temp. @ H-X Outlet	Provides indication of status of system and amount of Oxygen remaining thereby permitting a measure of max. time available for completion of mission.			0 to 100%, 20%/sec	1.25	2%	x	x	x	x	x					A premature exhaustion of the oxygen supply would make mandatory the early termination of the mission.
		Pressure Xducer		0 to 1000 psi, 200 psi/sec			x	x	x	x	x					
		Temp. Sensor		-300 to +100° F., 1°/sec												
		Pressure Xducer		0 to 5000 psi, 1000 psi/sec			x	x	x	x	x	x	x	x	x	
Pressurized Cabin Pressure @ Static Air Temp. @ Pt. Ave. 1 CO <sub>2</sub> Part. Pressure Inner No. 1 Skin No. 2 Temp. No. 3 No. 4	These measurements will provide an indication of the operation of the cooling system and the condition of the cabin.	Pressure Xducer		0 to 6 psio., 1 psi/sec			x	x								Excessive deviation from normal conditions will require corrective measure where possible. Should there be none available and should the astronauts be endangered an early termination of the mission may be necessary.
		Temp. Sensor		+40° to 200° F., 2°/sec			x	x	x	x	x	x	x	x		
		Temp. Sensor		0 to 20 MM Hg., 5 MM/sec	1.25	5%	x	x								
		Temp. Sensor		0 to 200° F., 5°/sec			x	x								
		Temp. Sensor		0 to 200° F., 5°/sec			x	x								
		Temp. Sensor		0 to 200° F., 5°/sec			x	x								
Pressure Suits Pressure Left @ Static Right Inlet Air Left Temp. Right Secondary Oxy. Rate CO <sub>2</sub> Partial Pressure	These measurements will provide an indication of both the operation of the system and the condition of the astronauts.	Pressure Xducer		0 to 6 psio., 1 psi/sec												
		Pressure Xducer		0 to 6 psio., 1 psi/sec	1.25	2%	x	x	x	x	x	x	x	x		
		Temp. Sensor		+50 to 100° F., 1°/sec												
		Temp. Sensor		+50 to 100° F., 1°/sec												
				B level	10	1s										
				0 to 20 MM Hg., 5 MM/sec	1.25	5%										

Table 4.1.3 - 1

GEMINI INSTRUMENTATION ANALYSIS  
Environmental Control System

Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Accuracy	Mission Essential	Contingency Backup	Check-out	Launch	Orbit	Retro	Re-entry	Descent	Recovery	Remarks
Coolant Outlet Temp.	To verify normal operation of system.	Temperature Sensor	+90 to +140°F, .5°/sec	1.25 2%		x		x	x	x	x	x	x	x	Should any of these measurements indicate improper operation depending on the degree of failure the mission may have to be terminated. e.g. should all pumps fail and all temperatures start to rise there will be a time limit on continued proper operation of the system.
Fuel Cell Temp. Cont. Valve - Prim.		Temperature Sensor	+30 to +80°F, .5°/sec												
Rad. Temp. Cont. Valve - Prim.		Temperature Sensor	+90 to +140°F, .5°/sec												
Fuel Cell Temp. Cont. Valve - Sec.		Temperature Sensor	+30 to +80°F, .5°/sec												
Rad. Temp. Cont. Valve - Sec.		Temperature Sensor	0 to 100°F, .5°/sec												
H <sub>2</sub> O Boiler Steam Temp.	To verify normal operation of system.	Temperature Sensor	Bilevel	10 .15		x	x	x	x	x	x	x	x	x	
Coolant Pump Failures			Bilevel												
Primary Loop - No. 1 Pump			Bilevel												
Primary Loop - No. 2 Pump			Bilevel												
Sec. Loop - No. 1 Pump			Bilevel												
Sec. Loop - No. 2 Pump	To verify normal operation of system.			1.25 2%		x	x	x	x	x	x	x	x	x	
Fuel Cell Coolant Temp.		Temperature Sensor	0 to 15°F, .5°/sec												
(Prim. Coolant Loop)		Temperature Sensor	0 to 15°F, .5°/sec												
Sect. 1. Coolant Temp. (Out to In)		Temperature Sensor	+80 to +180°F, .5°/sec												
Sect. 2. Coolant Temp. (Out to In)															
Sect. 2. Coolant Outlet Temp.	To verify normal operation of system.														
Fuel Cell Coolant Temp. (Sec. Coolant Loop)															
Identical to Primary Coolant Loop.															

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS				
Inertial Guidance System				
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate
Platform Attitudes	Indication to astronaut and ground attitude of spacecraft.	Inertial Package	0 to 360°, 20°/sec at 1 cps	NA
Pitch Gimbal				NA
Roll Gimbal (Inner)				NA
Roll Gimbal (Outer)				NA
Yaw Gimbal	Provide information on system operation particularly for post mission analysis.	Inertial Package	0 to 360°, 20°/sec at 1 cps	NA
Platform Accelerations				NA
Alongtrack $\dot{x}_p$				1.25 NA
Crosstrack $\dot{y}_p$				1.25 NA
Vertical $\dot{z}_p$	Provide information regarding alignment of system reference coordinates.	Inertial Package	±14 G, 7G / sec	1.25 NA
Platform Velocities				1.25 NA
Alongtrack $\dot{x}_p$				1.25 NA
Crosstrack $\dot{y}_p$				1.25 NA
Vertical $\dot{z}_p$	Provide indications of failure in system to astronaut and ground.	Inertial Package	0 to 25 Kfps, 320ft/sec/sec	1.25 NA
Platform Orbital Torqueing				1.25 NA
Pitch Torque Current				1.25 3%
Roll Torque Current				1.25 3%
Yaw Torque Current	Indication of fuel req'd to accomplish rendezvous.	Computer	0 to 20 MA	1.25 NA
Platform Malfunction Detection				1.25 NA
Accelerometer Malfunction				1.25 NA
Attitude Malfunction				1.25 NA
Computer Rend. Func's	Ind. of velocity change req'd to compl. proper rend.	Computer	Bilevel	10 ± 1s
Fuel Req'd for Rend.				10 ± 1s
ΔVel. Req'd During Rendezvous				0 to 300 Lb
Pitch Attitude Error				0 to 300 lbs
Yaw Attitude Error	Ind. of required corrections of pitch and yaw - to astronaut and ground.	Computer	± 20°	1.25 NA
				1.25 NA
				1.25 NA
				1.25 NA

Remarks

An improper indication here will set in motion contingency operations in the simplest case corrective positioning by the astronaut. These measurements will possibly have their greatest use for post mission analysis but it is conceivable that they could serve during the mission to point out impending problems.

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS																
Inertial Guidance System		Purpose of Information	Generating Instrumentation	Data Characteristics	Phase											
Parameter					Sample Rate	Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Launch	Pow. Flight	Orbital	Retro	Re-entry	Descent	Recovery
<u>Computer Re-entry Functions</u> Earth Latitude	Provide information to astronaut and ground as to location and stability of the spacecraft as it approaches the touchdown area.	Computer Generated	$\pm 45^\circ$ $\pm 180^\circ$ 0 to 200 NM $\pm 80$ NM $\pm 20^\circ$	1.25	NA											Should these signals indicate improper location, stability or approach conditions contingency operations will go into effect to either correct the condition or re deploy recovery forces to compensate for improper re-entry.
				1.25	NA											
				1.25	NA											
				1.25	NA											
				1.25	NA											
<u>Roll Att. Error</u>																
<u>I. G. S. Reg. D. C. Power</u> D. C. Voltage	Indication of proper operation of power supply.			+32 to +38VDC, .1V/sec	1.25	5%										Of interest primarily for purposes of engineering evaluation.

4.1.3-9

Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

GEMINI INSTRUMENTATION ANALYSIS																
Attitude Control and Maneuver Electronics																
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase										Remarks	
<u>Spacecraft Rates</u> Pitch Rate Roll Rate Yaw Rate		Inertial Package	±20°/sec, 3.5 cps	3%											This information will be used as a reference by the astronaut against which he can opr. to make corrections or changes.	
			±20°/sec, 3.5 cps	3%												
			±20°/sec, 3.5 cps	3%												
<u>Horizon Sensor Oper.</u> Output Pitch Sensor Output Roll Sensor Search Mode		Inertial Package	±20°, 10°/sec	1.25 1%											These signals will provide data for systems analysts and evaluation (post flight)	
			±20°, 20°/sec	1.25 1%												
			Bilevel	10 .1s												
<u>ACME Req'd Power</u> A.C. Voltage A.C. Frequency +24 VDC, B+ 9 VDC, bias -9 VDC, bias			23 to 29 VAC, .1V/sec	1.25 5%												
			380 to 400 cps, 1cps/sec	1.25 10%												
			Bilevel	10 .1s												
			Bilevel	10 .1s												
			Bilevel	10 .1s												

Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

GEMINI INSTRUMENTATION ANALYSIS																					
Astronaut Controls																					
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Checkout	Launch	Post Flight	Orbital	Retro	Re-entry	Descent	Recovery	Remarks				
<u>Attitude Control</u> <u>Stick Position</u>	Provide information on astronaut control of spacecraft attitude.		±10° .3 sec pulse	5%													All of these signals are of engineering interest for post flight analysis, however they may also serve to indicate inability of astronauts to handle ship. In this case precautionary measures or emergency assistance measures (if possible) will be initiated.				
				5%																	
				5%																	
<u>Translation Control</u>	Provide information on astronaut ability to maneuver the spacecraft particularly during the rendezvous and docking phases.		Bilevel, .3 sec pulse	10 .1s																	
				10 .1s																	
				10 .1s																	
				10 .1s																	
				10 .1s																	
<u>Paraglider Control</u>	Provide information regarding astronaut control of paraglider during landing operation.		Bilevel, .3 sec pulse	10 .1s																	
				1.25 2%																	
				1.25 2%																	
				1.25 2%																	
				1.25 2%																	
				1.25 2%																	



Table 4.1.3-1

## GEMINI INSTRUMENTATION ANALYSIS

Orbit Attitude Maneuvering System		Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase												Remarks
Parameter						Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Launch	Power Flight	Orbital	Retro	Re-entry	Descent	Recovery		
Propellant Storage Fuel (UDMH - Quantity N <sub>2</sub> H <sub>4</sub> )	Oxidizer Quantity (N <sub>2</sub> O <sub>4</sub> )	Provides indication of total remaining fuel.		0 to 100%, 20%/sec	1.25	2%	x	x	x	x							Should fuel run low mission requirements would either have to be reduced or eliminated depending on the quantity of fuel available.	
					1.25	2%												
Propellant Condition Fuel Feed Temp.	Oxidizer Feed Temp.	Indicates rate at which reaction will proceed.	Temperature Sensor	-20 to +150°F, .5°/sec	1.25	2%	x	x	x	x							Temperature readings out of range will indicate cautionary proceedings.	
					1.25	2%												
Pressurant (Helium) Condition	Pressure, Source He.	Provides a backup indication of propellant storage and primary indication of pressurant leakage.	Pressure Xducer	0 to 4000 <sup>psia</sup> , 800 <sup>psi</sup> /sec	1.25	2%	x	x	x	x							Malfunction may be sufficient reason to abort mission.	
					1.25	2%												
Temp. Source He.	Press. Regulated He.		Temperature Sensor	-60 to -200 F, .5°/sec	1.25	2%	x	x	x	x							Should these measurements indicate a malfunction in the thrusters, contingency operations will be set in motion.	
					1.25	2%												
Temp. Reg. He @ Fuel Tank	Oxidizer Tank		Temperature Sensor	-60 to 200°F, .5°/sec	1.25	2%	x	x	x	x								
					1.25	2%												
Thruster (TCA) Cond.	Temp., Injector Head	Provide engineering analysis information on typical thruster injector head temp	Temperature Sensor	- 50 to 300° F	1.25	2%	x	x	x	x								
Thruster Firing TCA No. 1	TCA No. 2	Provide indication of thruster operation to be used with system evaluation in conjunction with requirements as indicated by guidance systems measurements.	Solenoid Signals	Bilevel, pulse	10	.1s												
TCA No. 15	TCA No. 16						x	x	x	x								

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS											
Reaction Control System, (Retro and Re-entry)											
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Phase	Remarks	
									Launch		
									Orbital		
									Re-entry		
									Descent		
									Recovery		
Propellant Cond. System "A"	Provide information regarding condition of propellants from which it can be determined if they will flow and react properly.	Temperature Sensor	-20 to +150°F, .5°/sec	1.25 2%						Should unfavorable operating conditions be encountered the crew should proceed with caution until it has been established whether or not the system will function properly.	
Fuel Feed Temp.		Temperature Sensor	-20 to +150°F, .5°/sec	1.25 2%							
Oxidizer Feed Temp.											
Propellant Cond. System "B"											
Fuel Feed Temp.	Provides indication of pressurant leakage.	Temperature Sensor	-20 to +150°F, .5°/sec	1.25 2%						Malfunction may be sufficient reason to abort mission.	
Oxidizer Feed Temp.		Temperature Sensor	-20 to +150°F, .5°/sec	1.25 2%							
Pressurant(N <sub>2</sub> )Cond. Press., Source N <sub>2</sub> System "A"		Pressure Xducer	0 to 4000 <sup>PSIA</sup> 800 psi/sec	1.25 3%							
Press., Source N <sub>2</sub> System "B"		Pressure Xducer	0 to 4000 <sup>PSIA</sup> 800 psi/sec	1.25 3%							
Press., Reg. N <sub>2</sub> "A"	Primarily for providing engineering data to be used in post flight analysis and evaluation of system.	Pressure Xducer	0 to 400 <sup>PSIA</sup> 80 psi/sec	1.25 3%							
Press., Reg. N <sub>2</sub> "B"		Pressure Xducer	0 to 400 <sup>PSIA</sup> 80 psi/sec	1.25 3%							
Temp., Source N <sub>2</sub>		Temperature Sensor	-60 to +200°F, .5/sec	1.25 2%							
Temp., Reg. N <sub>2</sub> at Fuel Tank		Temperature Sensor	-60 to +200°F, .5/sec	1.25 2%							
Temp., Reg. N <sub>2</sub> at Oxidizer Tank		Temperature Sensor	-60 to +200°F, .5/sec	1.25 2%							
Thrustor Condition											
Injector Head Temp.		Temperature Sensor	-50 to +300°F	1.25 2%							
Retro Rocket Case Temp.		Temperature Sensor	0 to 250°F, .5°/sec	1.25 2%							

Table 4.1.3-1

GEMINI / INSTRUMENTATION ANALYSIS						
Reaction Control System (Retro & Re-entry)						
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Accuracy	Phase
						Recovery Descent Re-entry Retro Orbital Pow. Flight Launch Checkout Engin. Analysis Contingency Backup Mission Essen.
Thruster Firing System "A"	Provide indication of thruster operation to be used with system evaluation in conjunction with requirements as indicated by guidance system parameters.	Solenoid Signals	Bilevel, pulse	10	.1s	
TCA No. 1						x
TCA No. 2						x
TCA No. 7						x
TCA No. 8						x
Thruster Firing System "B"		Solenoid Signals	Bilevel, pulse	10	.1s	
TCA No. 1						x
TCA No. 2						x
TCA No. 7						x
TCA No. 8						x
Remarks						
Should these measurements indicate a malfunction in the thrusters, depending on the severity and effects, contingency operations will be set in motion. In this case contingency operations could easily mean a redeployment of recovery forces.						

GEMINI INSTRUMENTATION ANALYSIS													
Radar		Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase						Remarks	
Parameter						Accuracy	Mission Essen.	Contingency Backup	Checkouts	Launch	Orbital Flight		Re-entry
Target Angle	Provides signals for comparison with grd. tracking data as to relative Agena / Gemini positions	Voltage Monitor	-25° to +25°	1.25 NA									
Antenna Pitch Angle		Voltage Monitor	-20° to +20°	1.25 NA									
Antenna Yaw Angle													
Target Range	Provides indication to crew and grd. as to range and relative velocities of the crafts during rendezvous and docking maneuvers.	Voltage Monitor	10 to 1500 Kft. 500ft/sec	1.25 NA									
Radar Range		Voltage Monitor	-200 to +500 FPS	1.25 2%									
Radar Range Rate													
Radar Environment	Provides information on radar environment.												
Radar Inner Skin Temp. No. 1		Temperature Sensor	0 to 300° F. .5°/sec	1.25 5%									
Radar Inner Skin Temp. No. 2		Temperature Sensor	0 to 300° F. .5°/sec	1.25 5%									
Antenna Face Plate Temp.		Temperature Sensor	0 to 300° F. .5°/sec	1.25 5%									
Radar Pressurization Tx Tube Temperature		Pressure Xducer	0 to 15 .3 /sec	1.25 5%									
	Temperature Sensor	18° to 550° F. 10°/sec	1.25 5%										
Radar Operation	Provides engineering data on system to be used for verification of system performance.												
Tx Tube Current (R.F. Power)													
AGC Voltage													
AFC Voltage													
Power Supply Voltage													
Closed Loop Initiation			8 level		10 .1s								

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS		Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase														Remarks
Parameter	Accuracy					Mission Essen	Contingency Backup	Engin. Analysis	Checkout	Launch	Post Flight	Orbital	Retro	Re-entry	Descent	Recovery				
<u>Structural Temp's</u> Heat Shield Temp. No. 1 Heat Shield Temp. No. 2 Outer Skin Temp. No. 1 Outer Skin Temp. No. 2 Retro Pkg. Temp. No. 1 Retro Pkg. Temp. No. 2		Provides information for evaluation of heat shielding and dissipating devices, and for providing a record of temperatures encountered.	Temperature Sensor	-55° to +1000° F, 25°/sec	1.25 5%												Extreme temperatures indicating a danger to the crew would set in motion emergency operations.			
				-55° to +1000° F, 25°/sec	1.25 5%															
				-120° to +2000° F, 20°/sec	1.25 5%															
				-120° to +2000° F, 20°/sec	1.25 5%															
				-150° to +500° F, 1°/sec	1.25 5%															
				-150° to +500° F, 1°/sec	1.25 5%															
<u>Aerodynamic</u> Airspeed Static Pressure		Provides measurements required for evaluation and analysis of landing system operation.	Pressure Xducer	0 to 100 KFS	1.25 2%															
				0 to 15PSIA, 1PSI/sec	1.25 3%															
<u>Spacecraft Accelerations</u> Longitudinal		This is one of the measurements required for the determination of the re-entry parameters.	Accelerometer	-2 to +18G, 7G/sec																

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS																			
Physiological (Bio-Med.)				Phase															
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Accuracy	Mission Essen.	Contingency Backup	Engin. Analysis	Checkout	Launch	Pow. Flight	Orbital	Retro	Re-entry	Descent	Recovery	Remarks		
<u>Flight Commander (Left)</u> EKG, Electrocardiogram	Provides a measure of astronaut condition and heart activity.	EKG Electrodes	0 to 20 MV	480													If development is completed an impedance pneumograph may be used for this measurement.		
Blood Pressure	Provide a measure of circulatory sys. condition and its response to sys. environment changes.	Inflatable Occluding Cuff	0 to 20 MV	400		x	x	x	x	x	x	x	x	x			As presently conceived this measurement will be performed on request from flight surgeon, however, if developed in time an automatic BPMS may be used.		
Respiration Rate and Volume	Provides a measure of general astronaut condition and metabolic rate.	Anemometer	0 to 20 MV	160													If development is completed an impedance pneumograph may be used for these measurements.		
Skin Temperature	Provides indication of general astronaut condition.	Temp. Sensor	0 to 20 MV	1.25															
EEG, Electroencephalograph	Indication of activity level and astronaut condition.	3 sets EEG Electrodes	0 to 20 MV	960													This measurement from both crew men will be sent alternately at pre-programmed intervals over the same channel.		
GSR, Galvanic Skin Response	Provides indication of nervous activity.	Electrodes	0 to 20 MV	80															
Phonocardiogram	Provides information on hear condition and activity level.	Microphone		960															
<u>Radiation</u>	Provides measure of radiation level.	Dosimeter 3 Channels	0 to 5 V	1.25															
NOTE: For Flight Engineer (Right)																			
A duplicate set of monitors is provided as tabulated above for Flight Commander (Left.)																			

NOTE: For Flight Engineer (Right)

A duplicate set of monitors is provided as tabulated above for Flight Commander (Left.)

Table 4.1.3-1

GEMINI INSTRUMENTATION ANALYSIS										
Instrumentation and Digital Command System										
Parameter	Purpose of Information	Generating Instrumentation	Data Characteristics	Sample Rate	Phase					Remarks
Instrumentation Reference Voltages	Provide telemetry reference levels	Voltage Reference	DC level							
		Signal Common	DC level	1.25						
		Voltage Reference	DC level	1.25						
		Voltage Reference	Bilevel, 0 or 28 VDC	10	.1s					
		Voltage Reference	Bilevel, 0 or 28 VDC	10	.1s					
D. C. S. Code Checks Verification	Informs astronaut and ground that data has entered the using sys.		Bilevel, 15 MS pulse	80	NA					
D. C. S. Receivers										
Sig. Strength (AGC) Rcvr - A		Receiver	0 to 80 MV, 5 $\mu$ V/sec	1.25	2%					
Sig. Strength (AGC) Rcvr - B		Receiver	0 to 80 MV, 5 $\mu$ V/sec	1.25	2%					

#### 4.1.4 Position Sources

The information necessary to track and reacquire the vehicle is provided by the remote sites in the form of observations of the vehicle. Until a more detailed analysis is made, it will be assumed that during free flight, range, range-rate and angles at about ten points during a station pass are sufficient. This assumption is based upon prior Philco experience with similar space vehicle programs. For accuracy, those points should be smoothed from a greater amount of data rather than selection therefrom. During powered flight or reentry, more data is required.

A possible source of position information is found in telemetry data concerning acceleration. This may be of such poor quality, however, that the position and velocity integrated therefrom are of very low weight compared to the observations.

When the two vehicles are very close, the on-board radar will give the relative position. To enable the Gemini crew to effect rendezvous, this relative position and velocity information must be supplemented by the orbital elements of both vehicles, transmitted from IMCC. These elements define the motion of the center of the rendezvous coordinate system, which is probably at the vehicle which is least accelerated.



#### 4.1.5 Intra-GOSS Sources

Certain information requirements are satisfied by sources within the GOSS complex. Most of these sources exist in the tracking, computing, status, and timing subsystems. As the GOSS information requirements evolve, the iterative internal source analysis will correspondingly proceed.

#### 4.1.6 Extra-GOSS Sources

It is probable that additional sources of information, outside of the prime GOSS complex, will be utilized. Thus, weather facilities including the output of weather satellites may be required for one or more missions. The support of other tracking facilities may also be used, again, depending on mission or the requirements of a particular ephemeris.

## 4.2 DISPLAYS

### 4.2.1 General Considerations

There are at least three types of site where displays will be required to support specific phases of Gemini missions: the Launch Control Center (LCC), the Integrated Mission Control Center (IMCC), and the GOSS Remote Sites. In addition, there will be miscellaneous display requirements for the Recovery Control Center (RCC) within the IMCC building and for recovery forces on station, but since these requirements are less directly related to the spacecraft and their mission than to recovery force disposition, they are neglected in the following discussion.

Although the distinction may not always be clear cut, it is possible to categorize displays into two classes: Action Displays and Group Displays of mission progress.

#### 4.2.1.1 Action Displays

These are the auditory and visual displays of information provided to carry out the functions established as necessary by analysis of all aspects of Gemini missions. Action displays are the working tools for showing such things as the status of vehicle systems, astronaut condition, occurrence of sequential events in the flight plan and position data (e.g., attitudes, orbital parameters) on the spacecraft during the mission. Displays of this type will be provided at each class of site mentioned above, although the LCC will not include those remote site and IMCC displays which are concerned with later phases of the flight.

#### 4.2.1.2 Group Mission Progress Displays

Group displays are designed to provide integrated information on mission status on a real-time, near real-time and future time basis, to those managerial and operational personnel in the MOCR who have overall responsibility for the mission or some portion of it.

- a. Orientation and Training. Group displays will decrease the amount of time, effort and textual material needed to train operational personnel, by providing understanding of individual tasks in the context of overall operations. Closely related to this is the operational over-view such trained personnel can provide in mission planning, mission briefing, de-briefing, and in analyzing and interpreting data recorded during actual missions and during system exercises.
- b. Cuing Activities. During operations, group displays will provide an overall briefing which will serve as a reference for activities or events in "mission time." This is useful for "cuing" activities as well as for briefing during crew changes. Summary displays also include "predicted" mission information for planning control actions. (For example, display of predicted orbital ground tracks in relation to ground stations is useful for planning mission activities.)
- c. Personal Involvement of Flight Control Personnel. The manning concept that has been assumed for the MOCR is similar to that used in the present Mercury Control Room. Discussions with Flight Control personnel indicate without question that they want group information displays of mission progress. It appears that this is motivated by a desire for personal knowledge and an integrated view of mission progress beyond the isolated data provided by individual displays. This is a morale factor which should not be disregarded.

There may be times in Gemini missions when individual operators have very little to do; Group displays can provide the stimulation and interest needed to maintain alertness and vigilance during these periods. In addition, as stressed in the MIT report, lack of activity and current inability to influence the present or future course of the mission,

coupled with a sense of involvement and responsibility, may tend to produce anxiety and uneasiness among flight control personnel. If adequate summary information is provided to all, each individual can follow mission progress, even though no action is required of him during particular phases of the mission. This should help to prevent anxiety and contribute to flight control team solidarity, for no team member will feel that he is working in isolation.

- d. Observers. There has been considerable discussion on the location and kind of displays to be provided for observers not directly involved in operations. These displays can be similar or identical to the group displays provided in the MOCR. They may be remotely located, or the same displays may be used, by providing an acoustically-isolated observation room arranged to prevent interference with MOCR operations. An arrangement similar to the MCC should be considered to avoid duplication of displays. That there will be more requests for admission to such an area than can possibly be accommodated is recognized, but priorities will be necessary, regardless of where these facilities are located.

#### 4.2.2 Information Requirements for Group Displays

##### 4.2.2.1 General Considerations

In deciding what information shall appear on MOCR group displays, careful thought must be given to the purpose these displays are to serve, namely; to provide a general indication of GOSS status prior to and during the mission and to indicate progress of all phases of the mission from pre-launch to termination. On this basis, the following requirements should be considered:

- a. The information should be of general use, its utility should not be restricted to a small portion of the flight control personnel.
- b. Information displayed should provide both a general orientation and specific reference points for evaluating mission progress. The latter should include salient sequential events which occur during the mission. The displays should permit MOCR personnel to perceive the overall operation and to relate their own activities to the sequence of critical or milestone events which occur in "mission time."
- c. The display should indicate the consequence of certain critical actions if initiated at the present time. For example, the approximate impact point should be indicated if retrofiring occurs now. This kind of information cannot and need not be shown with any great detail of accuracy, since it will be displayed more accurately and in greater detail on individual consoles. In this particular case, for example, the indication of impact point need be no more than a circle which precedes the indicated vehicle along the orbital ground track, by an amount roughly equal to the predicted distance between retrofiring and landing.
- d. The displays should contain station status information for all ground stations in the network and indicate which station has vehicle contact. The status information should show the equipment available at each site (e.g., radar, voice communications, telemetry) and its status (Go or No-Go).

The concept advanced here is that the group displays of mission progress should not contain information on which specific decisions and actions are required (except for status data on the GOSS sites), but should be restricted to information of use to the majority of MOCR personnel in "cuing" their behavior to more specific information and events. This does not, however, preclude displaying significant mission events as they occur during the mission. The latter, for example, may include lift-off, time to retrofire, occurrence of retrofire, paraglider deployment, time to rendezvous, rendezvous completed and other significant events which occur during the mission. In general, this concept implies that the status of on-board systems and astronaut condition should not be displayed on the summary displays, but should be restricted to the individual consoles of the flight controllers most directly concerned, for these people are in a position to analyze the information and to take or recommend corrective or alternative actions, if necessary. For this reason, trend charts indicating variations in spacecraft systems and astronaut physiological parameters with time, should be restricted to those individuals who jointly or individually are best equipped to evaluate the significance of the trends.

The following section contains a preliminary and highly tentative listing of group display content, avoiding discussion of display techniques for the present.

#### 4.2.2.2 Group Display Content - Preliminary

Mission Progress. Group information on mission progress can be conveniently and meaningfully displayed by indicating time to go and successful completion of sequential events which constitute significant milestones in the mission plan. It will not be necessary nor desirable

to display the detailed sequence of events, but only those items which are recognized indications of mission progress. The information displayed will, in general, denote either the start or completion of a mission phase or the occurrence of a critical event, such as lift-off or retrofiring. The following preliminary list of display\* items is arranged by mission phase.

a. Checkout and Launch

- (1) Time to Launch: Countdown in hours, minutes, and seconds for Atlas/Agena and Titan/Gemini
- (2) Hold: Indicates count is being stopped temporarily.
- (3) Proceed: Indicates count has resumed.
- (4) Lift -off: Indicates powered flight has begun.

b. Powered Flight and Orbital Insertion

- (1) Titan Staging Complete: Indicates 1st stage cutoff and separation, and 2nd stage firing,
- (2) Spacecraft Separation Complete: Indicates 2nd stage cutoff and Gemini separation,
- (3) Gemini Orbital Insertion: Indicates that Gemini has achieved orbit,
- (4) Atlas Staging Complete: Indicates booster engine cut-off
- (5) Agena Separation Complete: Indicates sustainer engine cut-off, Agena separation and starting of engines
- (6) Agena Orbital Insertion: Indicates that Agena has achieved orbit.

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\*Display includes both auditory and visual modes of presentation. Some of the information requirements enumerated here are presently displayed via auditory mode for Mercury. Modes and types of displays will be considered in another report.

## c. Orbit and Rendezvous

- (1) Orbit Path: Once insertion is achieved, the actual position of the vehicle along a predicted orbit path should be displayed in relation to ground station coverage. Ground station coverage will vary depending on orbits and may have to be displayed at other than nominal values for a "typical" orbit. Displaying predicted orbits for two vehicles for the entire mission is necessary to plan appropriate actions. If displayed in a manner similar to Mercury, this would clutter the display to such an extent that interpretation would be difficult and confusing, and would likely result in errors. Plane change predictions should be displayed so that changes in orbit path will not alarm control personnel. (This could be displayed as time information--Time to re-start for Agena, Time to start OAMS for Gemini.)
- (2) Rendezvous: Indicates predicted location of rendezvous (docking) and separation in relation to ground stations; indicates where docking and separation actually occur.

## d. Retro and Reentry Sequence

- (1) Estimated Time to Retrofire: Indicates when retrofire is to occur
- (2) Retrofire: Indicates that retrofire has occurred
- (3) Paraglider Deployed: Indicates that sequence up to and including paraglider deployment is complete

## e. Descent with Lift, Landing and Recovery

- (1) Paraglider Inflated: Indicates sequence from deployment to inflation is complete
- (2) Estimated Time to Landing: Indicates when landing is to occur
- (3) Predicted Impact Point: Indicates where landing and recovery are to occur.



Status of GOSS Elements. This information is intended to portray GOSS network status during the network countdown immediately preceding the mission, and to provide a continuing status indication as the mission proceeds. In general, there are two types of status information within GOSS: (1) equipment condition, and (2) mission events involving GOSS elements.

a. Equipment Condition

(1) Remote Site Status

Station Status: Inoperative, or incapable of performing mission objectives for the site; operative, or capable of performing mission objectives

Station Subsystems Status\*: If incapable of performing mission assignments, indicate which system (or systems) are out. This includes such systems as: Data Processors, Telemetry Receiver (s), Command Transmitter, Command Encoder(s).

(2) Communication Links: Indicate inoperative link between any two GOSS elements, indicate operative links between GOSS elements

(3) IMCC

IMCC Status: Operative and capable of performing mission, inoperative or incapable of performing mission

IMCC Systems Status: For IMCC systems, indicate operative or inoperative (IMCC may be operative and some systems inoperative, depending on standby equipments or backup redundancy, but still need status of

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\*As a memory aid to all Flight Controllers, it is desirable to indicate station composition by system.

systems for planning purposes, for example, may decide to continue a mission if the system out can be brought back in as standby within some specified time).

(4) Computer: Indicate operative or inoperative

b. GOSS Events

(1) Remote Sites: During a mission, the occurrence of certain remote site events is indicated to IMCC. These status indications are:

(a) Tracking: Site locked-on and tracking vehicle (Gemini or Agena)

(b) Communicating: Site in communication with vehicle, either by voice, or on the command or telemetry links.

c. GOSS and Vehicle Time

Time will be a critical factor in initiating and monitoring the occurrence of major events during a Gemini mission or system exercise, and in fact, the successful accomplishment of this time sequence of events will be a major cue to mission progress. Therefore, all system activities must be referred to a universal time, probably GMT. Some of the time display requirements below were listed previously in the section on mission progress, and are repeated here merely for convenience in grouping time information together.

(1) Universal System Time

Hours, minutes and seconds as a standard reference for all system elements, including the Gemini spacecraft

(2) Mission and Vehicle Elapsed Times

Time since lift-off in days, hours, minutes and seconds (it may also be desirable to have an indicator showing elapsed time in hours, minutes and seconds, but both of these need not be on the group information displays). These will be elapsed times for each vehicle, common to all ground stations, which can be used to anticipate the occurrence of time critical events during the mission.

### (3) Miscellaneous Sequential Event Times

These have been mentioned previously. They consist either of "time remaining to" (countdown) or time of occurrence (estimated or actual) displays. For certain events, the countdown, the estimated and the actual time of actuation may all be of interest to certain individuals in the MOCR, but this much detailed information seems inappropriate for the group displays.

#### (a) Time to Launch

"Countdown" in hours, minutes and seconds. It is expected that the Gemini and Agena will use the same display unless countdowns overlap.

#### (b) Time to Plane Change

This can be time to restart for Agena, time to start OAMS for Gemini.

#### (c) Rendezvous Time

This can be a countdown, an estimate of time that rendezvous will occur or a display indicating actual time of rendezvous.

#### (d) Docking Time

See remarks on rendezvous time

#### (e) Separation Time

The above remarks apply

#### (f) Time to Retrofire or Time to Initiation of Retrosequence

This can be an estimate, a countdown or an indicator of time of actuation.

#### (g) Time to Landing

Above remarks apply.

It appears desirable to restrict time display of this type (on the MOCR group displays) to a single indicator for each event. It may be feasible to time several non-overlapping events on a single indicator, by providing appropriate "tags" for each event time so displayed. Since these time displays are for general information, and no action is required, there is no reason for providing countdown type displays except for the launch countdown, which is of general interest. Displays of estimated time, corrected upon actual occurrence of events, should be sufficient.

### 4.2.3 Information Requirements for Action Displays

#### 4.2.3.1 General Considerations

Action displays were previously defined as the working tools for displaying such things as the status of vehicle systems, astronauts' condition and other information deemed essential for the decisions and actions required of flight controllers during a mission. In contrast to group information on mission progress, which is available to all MOCR personnel, action information must be categorized in terms of mission functional requirements and allocated to individuals in terms of appropriate division and assignment of responsibility.

The purpose of the present discussion is two-fold: (1) identify and define functional operations necessary for the MOCR to accomplish its mission and (2) specify the information required and available to perform these operations. The functional operations, which include spacecraft systems monitoring, biomedical monitoring, flight dynamics monitoring and other operations, are to be considered as task categories for which information requirements can be derived. These operations and information requirements, in turn, have implications for division and assignment of responsibility, and for manning requirements. Insofar as possible, considerations of the latter aspect will be deferred so that concentration on information requirements for dis-

plays and on preliminary consideration of display characteristics, is possible.

#### 4.2.3.2 Functional Operations Requirements

These operations, taken together, define the functions required in the MOCR as the central element in the IMCC. The present discussion does not include all functions of the MOCR, but is restricted to those which appear to be most critical from the standpoint of information requirements and display. These critical categories are first enumerated below, then, in following sections, each is defined and characterized in terms of the information necessary and available for performing the functions assumed necessary.

It should be emphasized that both the categories and their information requirements are tentative, and that they are by no means mutually exclusive. The functions themselves may overlap, and their information requirements almost certainly will, for identical information, and may be required for somewhat different uses. The categories considered are:

- a. Flight dynamics monitoring
- b. Spacecraft systems monitoring
- c. Biomedical monitoring
- d. Voice communication, spacecraft-to-ground and ground-to-spacecraft.

Each of these categories may, in turn, include various subcategories of information monitoring.

#### 4.2.3.3 Information Requirements for Flight Dynamics

##### 4.2.3.3.1 General Considerations

Flight dynamics information includes, but may not be limited to, the following kinds of data: (1) information on the normal occurrence of sequential and other events during the mission, (2) information on the occurrence of emergency actions, (3) time information on mission events (countdowns and estimated times of initiation) and (4) location coordinates and their derivatives (e.g., velocity, acceleration, range rate, etc.) for the Gemini and the Agena.

The flight dynamics officer\* (FDO) is responsible for monitoring sequential events (e.g., lift off, first stage cut-off, second stage ignition and cut-off, spacecraft separation, etc.) which occur during powered flight, for determining if powered flight parameters (e.g., velocity, velocity vector, etc.) are appropriate for the desired orbit, for deciding which maneuvers are most appropriate for accomplishing rendezvous, and for monitoring Gemini reentry. This listing, though by no means exhaustive, is sufficient to indicate the critical nature of the

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\*These terms are used primarily to indicate areas of responsibility. The duties may actually be shared by two or more individuals.

flight dynamics function. In the following sections, flight dynamics duties are examined in detail, starting with pre-launch and ending with mission termination.

In interpreting the tentative information requirements which follow, two things should be kept in mind. (1) Certain information items listed may not be displayed directly in the flight dynamics area, yet they must be taken into account in making decisions. Choice of alternative maneuvering schemes, for example, depends on fuel availability, but it may be inappropriate to display detailed information on spacecraft fuel and other systems to the FDO. (2) Where decisions, actions or commands are listed or implied, they are not meant to imply a particular command scheme. As used here, "commands" may include advice, recommendations and data transmitted to the Gemini crew, stored program commands and initiating signals transmitted to Agena, as well as real-time commands to Agena.

#### 4.2.3.3.2 Launch, Powered Flight and Orbit Insertion

- a. Requirements, General. Monitor booster and spacecraft performance, event sequence and flight geometry during powered flight and insertion. Compare with normal event sequence, and planned flight and insertion geometry. Watch for occurrence of emergency events.
- b. Decisions/Actions, General. If Gemini event sequence is incorrect (e.g., spacecraft doesn't separate) or insertion parameters extreme (e.g., extreme over-velocity), may recommend



abort to Flight Director, inform crew and Range Safety. Insertion parameters of either Gemini or Agena may be outside limits for accomplishing rendezvous, for range safety, or both.

c. Information Available

(1) Event Sequence, Titan/Gemini

Source: Telemetry from vehicle and radar tracking via Cape Canaveral (LCC, GE/Burroughs facility, etc.) to IMCC.

Action: If event sequence or timing faulty, may recommend crew or LCC initiation of events as appropriate, or recommend abort if necessary.

Display Items:

- (a) Firing Signal: indicates LCC has initiated launch
- (b) Lift-Off: indicates start of Titan powered flight; start of Gemini elapsed time (GET) and mission elapsed time (MET), if Gemini launch first
- (c) First Stage Cut-Off (FSCO): self-explanatory, indicates staging progress
- (d) First Stage Separation: self-explanatory, progress
- (e) Second Stage Firing: self-explanatory; Titan staging complete
- (f) Second Stage Cut-Off (SSCO): self-explanatory
- (g) Posigrade Rockets Fired: indicates that separation rockets were fired
- (h) Gemini Separation: self-explanatory
- (i) Guidance Status: Go, trajectory correct, Titan obeying guidance system. No-go, Titan not responding correctly to guidance commands

- (j) Orbit Go, No-Go: computer recommendation on basis of powered flight and insertion parameters
- (k) Orbit Capability: a computer estimate of the number of orbits possible on basis of insertion parameters.

(2) Event Sequence, Atlas/Agena

Source: Telemetry from missile and radar tracking via Cape Canaveral (LCC, GE/Burroughs facility, etc.) to IMCC.

Action: If event sequence or timing incorrect, may recommend LCC initiation of events or recommend abort.

Display Items:

- (a) Firing Signal: indicates LCC has initiated launch
- (b) Lift-Off: indicates start of powered flight, start of Agena elapsed time (AET) and of MET if Agena launch first
- (c) Booster Engine Cut-Off (BECO): indicates staging complete
- (d) Substainer Engine Cut-Off: self-explanatory
- (e) Agena Separation: self-explanatory
- (f) Guidance Status: Go, trajectory satisfactory, missile reacting to guidance system. No-Go, vehicle not responding correctly to guidance commands
- (g) Orbit Go, No-Go: computer recommendation based on powered flight and insertion parameters
- (h) Orbit Capability: computer estimated number of orbits possible on basis of powered flight and insertion parameters.

(3) Emergency Events

Display Items:

- (a) Abort Recommend: indicates an abort request generated by Range Safety, by flight controllers in IMCC or by the crew (for Gemini)
- (b) Abort Command: telemetry indication from vehicle that abort has been initiated
- (c) Seat Ejection Initiate: (separate indicators for each seat) indicates seat ejection mechanism has fired.

(4) Powered Flight and Insertion Geometry

Source: Radar tracking data from Cape Canaveral to IMCC computers. Computer processing for display of time, smoothed present position and for prediction.

Action: If powered flight and insertion parameters are outside established safe limits, will recommend abort of Gemini or Agena. If outside limits required for rendezvous attempt, must notify Flight Director and crew.

Display Items:

- (a) Gamma: the angle between missile velocity vector and local horizontal; compared with known acceptable limits
- (b) Velocity vs. Altitude: self-explanatory; compared with acceptable values
- (c) Altitude vs. Range: self-explanatory; compared with acceptable values
- (d) Velocity Ratio: indicates the ratio between present and desired velocity
- (e) Velocity Ratio vs. Gamma: this is the most critical information parameter for orbital insertion. If either Gamma or the velocity ratio are outside certain limits at insertion (and they are interdependent) the orbit may not be acceptable for crew safety or for achieving rendezvous, or both

- (f) Longitudinal Acceleration: telemetered from booster or spacecraft; indicates acceleration along the powered flight path
- (g) Inertial Velocity: computer estimate; displayed as a function of time remaining to SECO (Agena) and as a function of time remaining to SSCO (Gemini)
- (h) Predicted Insertion Altitude: computer estimate; indicative of guidance system performance and acceptability of present trajectory to satisfy altitude criterion
- (i) Perpendicular Velocity Component: telemetered from booster or spacecraft; indicates velocity perpendicular to desired flight plane; guidance system performance and acceptability of present trajectory
- (j) Yaw Deviation: deviation to right or left of the desired powered flight track, telemetered from booster or spacecraft.

(5) Event Times

- (a) Launch Countdown First Vehicle: the launch countdown for the vehicle to be launched first
- (b) Launch Time Second Vehicle: indicates second vehicle launch time limits acceptable for achieving rendezvous
- (c) Launch Countdown Second Vehicle: self-explanatory
- (d) Gemini Elapsed Time (GET): time elapsed since Titan lift-off
- (e) Agena Elapsed Time (AET): time elapsed since Atlas lift-off
- (f) Mission Elapsed Time (MET): time elapsed since lift-off of first vehicle.

#### 4.2.3.3.3 Summary

Heading I through V above are classes of information considered essential to performing flight dynamics functions during the phase lasting from launch through orbit insertion. The display items included in each group may not be complete; for example, there may be intervening steps between certain of the sequential events which occur during launch and powered flight. Further analysis of spacecraft, booster systems and mission profiles will uncover missing items which should be considered in display planning.

The following section deals with flight dynamics responsibilities during orbit and rendezvous.

#### 4.2.3.3.4 Orbit and Rendezvous

General Requirements. Monitor orbital parameters based upon computer-processed tracking data. Compare, evaluate and select alternative maneuver programs on basis of computer-generated future time displays,\* considering energy requirements and availability, time required and crew safety. Primary flight dynamics responsibility is to determine if rendezvous should be attempted and to evaluate alternative maneuver programs by which it may be achieved.

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\* Future time displays are of two types: (a) predicted orbit, etc., based on past tracking data, etc., and (b) predicted orbits based on assumed data or actions and predicting their affect on orbits, trajectories, plane changes, etc. For example, there will probably be a family of "commands" versus times for effecting a plane change or catch-up maneuver. Depending on status of vehicle and GOSS elements as well as other ground rules, such as rendezvous over a particular area, one would want to see the effect of such "command" before actually initiating the command (for the Agena) or requesting the crew to take action (for Gemini). In this way, consequences of proposed actions as generated by the computer can be evaluated prior to taking the action or recommending that a certain action take place.

General Decisions/Actions. Are orbital parameters suitable for a rendezvous attempt during this mission? Recommend maneuver programs to Gemini crew. Select appropriate Agena maneuvers, initiate Agena real-time and/or stored program commands.

Information Available. Information available is described in the following paragraphs.

#### I. Orbital Parameters and Status Information (Both Vehicles)

Source: IMCC computers generate real-time and future time displays from tracking data received from GOSS network. Status information may be obtained from vehicle systems and biomedical monitors, on request.

Actions: Primarily monitoring but also must determine if orbits are acceptable for rendezvous attempt.

##### Display Items:

- (1) Altitude versus time: indicates Apogee and Perigee, eccentricity of orbit
- (2) Inclination Angle: indicates the angle between the orbital plane and the earth's equatorial plane
- (3) Orbit Eccentricity: indicates orbital eccentricity as a function of elapsed time. Used in conjunction with item 4
- (4) Spacecraft Systems Status (both vehicles): Summary status of vehicle systems, such as propulsion and attitude control. May not be displayed to flight dynamics personnel directly, but evaluation obtained from spacecraft systems monitors, on request.
- (5) Crew Status: indicates whether astronauts' medical and emotional condition is satisfactory. Evaluation to be obtained from biomedical monitors, rather than by direct display to flight dynamics personnel.

The above information on orbital parameters, and vehicle and crew status will be used to determine if a rendezvous attempt is feasible. Flight dynamics personnel will rely on computer estimates and predictions, and on future time as well as real-time displays generated by the computer complex. Orbital parameters may be displayed numerically, by plots of spacecraft coordinates or both. Crew and vehicle status

information should be evaluated by spacecraft systems and biomedical monitors rather than by flight dynamics personnel. The FDO may query the appropriate personnel and receive a visual or auditory go or no-go indication in reply.

## II. Rendezvous Maneuver Evaluation (Both Vehicles)

Source: Evaluation and choice of alternative maneuvers will be based on real and future time displays, computer recommended alternatives, spacecraft systems evaluation (e. g. fuel availability) crew status, time requirements, fuel requirements and safety.

Actions: Evaluate and select maneuvers. Recommend crew action and verify. Insure that appropriate real-time commands, stored-program commands and/or initiation signals are transmitted to Agena. Evaluate subsequent maneuvers. Select from available computer program repertoire for solving maneuver problems and evaluate computer recommendations.

### Display Items:

- (1) Repertoire of available computer maneuver evaluation programs (possibly tabular, or obtained by request and consultation with computer personnel).
- (2) Computer predicted rendezvous maneuvers: indicates the future spacecraft coordinates and derivative quantities if particular maneuvers are initiated. May be displayed numerically or on coordinate displays.
- (3) Computer predicted energy requirements: self-explanatory
- (4) Computer predicted time requirements: self-explanatory.
- (5) Real-time displays: spacecraft location coordinates or derivative quantities, such as velocity, acceleration, range rate, etc. May be displayed numerically, or by coordinate plots, or both.
- (6) Spacecraft Systems Status (both vehicles): See Items 1-5, above.
- (7) Crew Status: See Items 1-6, above.

The items, enumerated above, will enable flight dynamics personnel to evaluate and select optimum maneuvers using real-time displays, predictive displays and computer-recommended alternatives.

For a discussion of the concept of a man-computer combination to perform flight dynamics monitoring, see paragraph 4.2.3.3.5.

### III Maneuver Monitoring (Both Vehicles)

Sources: These are envisioned as (1) computer-generated displays both predictive (generated by computer prediction based on orbital history and thrust parameters for the selected maneuver) and real-time (generated by computer from actually attained thrust parameters indicated by vehicle telemetry, telemetered attitude at initiation of maneuver, and smoothed and integrated tracking data from GOSS sites), (2) event indicators and (3) time indicators. Sources for the latter two display classes are vehicle telemetry received directly or via GOSS sites.

Actions: The actions required in response to the information may range from selection of following maneuvers to recommending abort, depending upon the results achieved and whether events occurred in correct time sequence.

#### Display Items:

- (1) Location Coordinates: indicate location (and derived quantities such as velocity, acceleration and range rate) during and following maneuvers. These may be numerical displays or coordinate plots and may be identical to the orbital displays discussed earlier. These displays should be provided with variable scales to take maximum advantage of the computer accuracy and resolution, and to show final approach and rendezvous in all possible detail.
- (2) Sequential Events: indicate that significant events have occurred in Agena and Gemini (or perhaps separate indications will be telemetered from both vehicles, for certain critical events). Probable display items are listed separately below.
  - (a) Rendezvous Radar On: telemetry, voice or both from Gemini
  - (b) Radar Contact: indicates radar detection of Agena. Source is Gemini voice, telemetry and possibly Agena Telemetry.
  - (c) Radar Lock-on: indicates Gemini radar is locked on to Agena transponder.
  - (d) Coplanarity Achieved: indicates vehicles in same orbital plane: Source is tracking from GOSS, computer evaluation.



- (e) Visual Contact: Gemini crew has sighted Agena visually. Source is Gemini voice.
- (f) Gemini Command Control: indicates that Gemini has Agena command (this depends upon the command scheme, and may not be used) source; Gemini voice telemetry, Agena telemetry.
- (g) Docking Mechanism Extension: indicates that docking apparatus has extended from Gemini and/or Agena. Source may be Gemini voice telemetry and Agena telemetry.
- (h) Coupling (1) Mechanical and (2) Electrical: indicates that vehicles are (1) mechanically and (2) electrically coupled. Source; Gemini telemetry and voice, Agena telemetry.
- (i) Coupled Maneuver Initiate: self explanatory. Source: Gemini voice telemetry, Agena telemetry.
- (j) Uncoupling, Mechanical and Electrical: See item (h).
- (k) Docking Mechanism Retract: See item (g).
- (l) Separation: may involve thrusters on one or both vehicles.

In addition to these events which will occur in some sequence (not necessarily in the above order, however), there are others for which indicators may be provided. These are listed below and are largely self-explanatory.

- (a) Agena Main Engine Restart
- (b) Gemini Velocity Thruster Reburn

Other thrusters may be fired on each vehicle to maintain and control attitude, but it may not be appropriate to provide event indicators for each one since the change in attitude will ordinarily be apparent on other displays, although perhaps not in the flight dynamics area.

- (3) Rendezvous Event Timing: these are estimated times remaining until events occur, or in some cases, elapsed time since occurrence. The list below is tentative; further analysis may prove that certain items are not necessary; while others not included here may become apparent.
  - (a) Time Remaining to Maneuver Initiation: these indicate estimated times remaining until the initiation of the initial maneuvers required to correct ellipticity, to achieve coplanarity and to perform later maneuvers in the terminal phases of rendezvous. There may be several of these for Agena (restarts) and fewer for Gemini, due to its limited propulsion capability. Source; computer estimates based on orbital parameters, rendezvous maneuvers to be employed and desired rendezvous location.

- (b) Time to Rendezvous Radar Control: a computer estimate of the time remaining until Gemini will obtain radar contact with Agena, based on orbital parameters
- (c) Time to Docking: a computer estimate based on orbital parameters, rendezvous maneuver mode and desired rendezvous location
- (d) Time Since Docking: elapsed time since mechanical coupling
- (e) Time to Separation: a computer estimate based upon orbital parameters, desired location for separation, fuel availability and the recovery plan.

#### 4.2.3.3.5 Summary

Subsection 4.2.3.3.4 I dealt with Orbital Parameters, Section 4.2.3.3.4 II considered the information requirements for evaluating alternative maneuvers, while Subsection 4.2.3.3.4 III considered the information needed to monitor the vehicles during maneuvers. The information falls generally into three classes: (1) location coordinates of derivative data on spacecraft position, such as velocity, acceleration and range rate; (2) occurrence of events, usually in some sequence; and (3) time information. The next sections, which cover flight dynamics functions during re-entry and recovery, will follow a similar scheme.

#### 4.2.3.4 Information Requirements for Life Support Control System Displays.

4.2.3.4.1 Display Concept. The general information requirements for the crew, biomedical experiments, environment and ECS monitoring functions have been defined in a previous section. The information which is obtained from the spacecraft will be analyzed and trends will be obtained from it. All of this data, both original data and necessary deviations, will be displayed in the IMCC. A subsequent section of this report contains a possible information plan for the life support systems data to which the reader is referred as an aid in understanding the following discussion. As with all of the display subsystems, the life support display system must be flexible enough to accommodate the different displayed information requirements for different missions as well as to accommodate unforeseen, last-minute changes in these requirements. Using this concept of flexibility as the primary constraint, a display system has been conceived which requires no real-time analog or digital displays at the consoles in the MOCR. With this system, tolerance limits would be set for as many parameters as possible. "Go, No-Go" indicators at the consoles would be activated by signals from the limit determination data processing equipment. The legends on these indicators and the associated sources would be changed whenever the requirements for displayed information were changed. The primary display devices would be television monitors which would display data selected from that which is displayed or generated in the support area. Television sensors would be placed in the support area in such a manner that information displayed at the consoles would still be visible to operators in the support area. It is anticipated that functions such as comparing real-time information with historical information, and monitoring concurrently at least two kinds of data (such as biomedical and environmental) would probably require at least two TV monitors using split screen techniques at each of the two consoles in the MOCR. The console operators would have controls which would enable them to select any of the information available in the support area for their respective fields of interest. Since the displays at the consoles would be images of

the displays which are present in the support area, the following paragraphs will describe only those displays within the support area.

4.2.3.4.2 Crew Monitoring Display Requirements. The following parameters will be displayed for each astronaut. For purposes of illustration only, specific display techniques will be referenced to support these requirements. The actual devices to be recommended will be dependent upon later analyses to be submitted in a separate report dealing with performance requirement specifications.

Respiration Rate and Volume. The respiration waveform will be recorded on a strip chart recorder to indicate the rate of breathing and tidal volume of air. In addition, the respiration rate will be automatically derived and presented by means of a digital display.

Skin Temperature. The primary mode of presentation for skin temperature will be by means of a digital readout. Temperature trends will be recorded on a strip chart recorder.

Blood Pressure. The pressure waveform containing the Korotkov sound indications will be recorded on a strip chart recorder. From this chart, the systolic and diastolic pressures will be interpreted by a support area operator, or possibly by data processing equipment. Blood pressure will be entered into a digital display device.

Electrocardiogram (EKG). The EKG will be presented on a strip chart recorder.

Pulse Rate. Pulse rate will be derived from the peaks of the EKG waveform and will be displayed on a digital readout. The rate will also be recorded on a strip chart recorder for correlation with mission events.

Verbal Reports. The astronauts' verbal reports will be monitored. Comments regarding their environment and health, and their impressions of the health and well being of each other will be recorded.

4.2.3.4.3 Biomedical Experiments Display Requirements. The phonocardiogram, electroencephalograph and galvanic skin response readouts will be presented on a strip chart recorder. These data will not be analyzed on a real-time basis. Hence, no requirement exists for

their presentation to the Biomedical and Environment monitor in the MOCR. When biomedical experiments are run using the biomedical sensors as investigative tools, the readouts will be correlated with the experiment event by the personnel within the support area.

4.2.3.4.4 Environment Monitoring Display Requirements. The following items will be monitored by means of digital readouts or meters.

- a. Cabin oxygen partial pressure
- b. Cabin pressure
- c. Cabin temperature
- d. Suit pressures
- e. Suit inlet air temperature
- f. Cabin carbon dioxide partial pressure
- g. Suit carbon dioxide partial pressure
- h. Radiation dosimetry

In addition to readouts of these parameters, trend charts will be generated to yield information about potential environment hazards.

A status light will be used to indicate the setting of the secondary oxygen rate valve. Acceleration will be presented on a strip chart recorder and will be used as a baseline against which biomedical data will be examined for powered flight, maneuvering and reentry.

4.2.3.4.5 Environmental Control Systems Monitoring Display Requirements. The ECS monitoring function is incorporated into the Life Support Systems area because of its direct bearing on the environment and, consequently on the physical condition of the crew. These parameters will be displayed on digital readouts and meters. In addition to these readouts, the time remaining before the oxygen supply will be exhausted will be derived from the data and displayed as will trends for the remaining parameters.

4.2.3.4.6 Other Display Requirements for Life Support Systems. A readout will be required for the historical information which is developed during the flight. A data summary printer will perhaps be required for data which is to be reduced automatically. File displays will be needed for the verbal report, astronauts' health history, and data irregularity files.

4.2.3.5 Information Requirements for the Remaining Functions in the MOCR and Support Area, the Remote Sites, and Recovery Control Center. Information requirements for displays for the functions in the MOCR and support areas are incomplete at this time for all functions except those described in previous sections of 4.2. As the requirements are developed, this section will evolve into a description of information requirements for display at each defined position (or console) within the MOCR and Support areas of the IMCC. The same is true of information requirements for displays at remote sites and recovery control center.

### 4.3 OPERATIONS AND PROCEDURES

#### 4.3.1 Scope

As used in this report, operations and procedures are meant to include the various constraints which must be considered in the flow of information between elements of the system. These constraints include: (a) the inter- and intra-communication which are affected either by personnel and the organization thereof and the "state of the art" of communication equipment; (b) the interrelationships of various organizations involved in the overall mission, e. g. , military communication networks as part of the recovery phase of a mission; and (c) the factors involved in trade-offs between data handling and procedures, such as availability of data handling equipment in time for Gemini rendezvous missions and the relative reliability of manual processing as opposed to machine processing.

## 4.4 DATA HANDLING

### 4.4.1 Scope

As used in this report, data handling is meant to include the transfer-  
ence of data between elements of the system, including rate changes.

Specifically excluded from the data handling category are the processes  
of transforming data to change its nature by abbreviation, expansion,  
re-encoding, or computation.



## 4.5 DATA PROCESSING

### 4.5.1 Scope

As herein used, data processing is defined to mean the transformation of raw data involving various smoothing, formatting and computation operations.

To determine the extent that data processing accommodates the information requirement concerned, the operations involved in the processing will be examined in some detail. The data that is under study includes all telemetry interchange between the spacecraft and GOSS as well as the treatment of data between GOSS elements.

Initially, this report will be confined to the presentation of position information data pending the examination of other data requirements.

No specific type or quantity of data processing is implied or recommended at this time. Justification for such data processing will be substantiated by analysis in later reports. However, a discussion in this area is warranted relative to some of the alternative considerations involved in the formulation of an information flow plan to satisfy information requirements.

#### 4.5.2 Position Information

The purpose of the tracking(and other position)information is to determine the past, present, and future flight paths of the vehicle. The position data also provide data to satisfy several related functions. It is used to generate the acquisition data to ensure that the remote sites track the vehicle on each pass. It also provides impact prediction points so that the final descent destination of the vehicle may be known with some accuracy. Abort and alternative mission profiles are computed continuously during the flight of the vehicle, which is one of the most important tasks for which the position information is used.

There are several position information displays on which current information must be maintained during the flight of the vehicle. The position information is also used for the mission scheduling. For instance, it will keep a record of time until retrofire, etc. The information will also be necessary to determine mission parameters such as launch window for second vehicle, impulse required for rendezvous, or orbital life time.

The position information will account for a large share of the computations performed at the IMCC. It will also be a large segment of the information received at the remote sites. The details of this information flow and processing are discussed in the following paragraphs.

##### 4.5.2.1 Position Data

The kind of position data, received at a remote site, consists largely of tracking data. There is some acceleration information, and perhaps the results of the Gemini on-board radar will be available through telemetry. This information may be processed to some

extent at the remote site and sent on to the IMCC. In this regard, it would be advisable to perform a smoothing process on the tracking data.

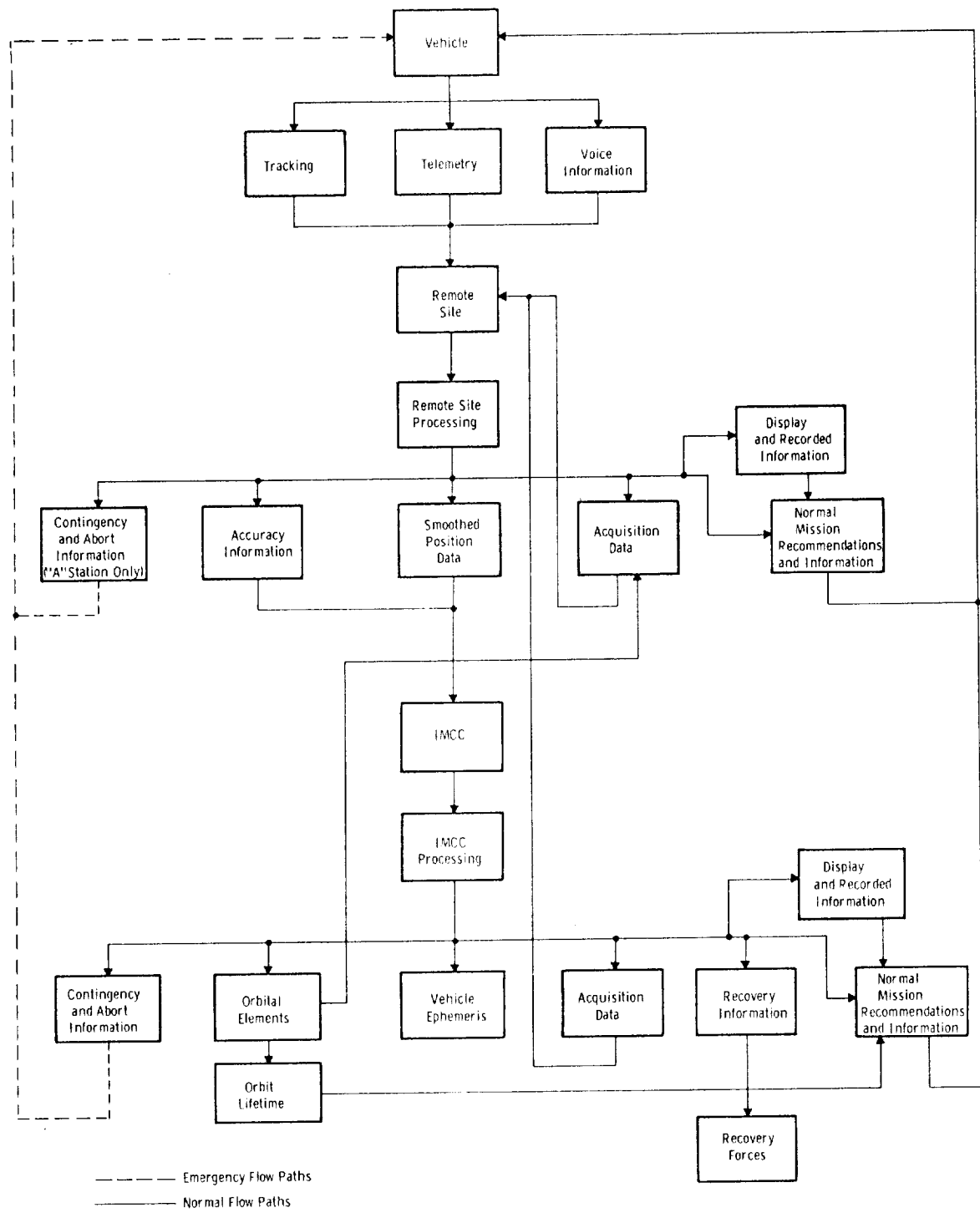
The remote site could also provide an accuracy evaluation of the information it is relaying to the IMCC. It is efficient and advisable to perform this function at the remote site. An error detection and decision feedback system is helpful. The smoothed and evaluated data is relayed to the IMCC where it is incorporated into the main computational sequence, at which point the main mission support analyses are performed.

More details of the processing, smoothing, and accuracy evaluation are included in the following paragraphs.

4.5.2.1.1 Position Information Flow Plan. The position information flow plan will be discussed with the aid of Figure 4.5.2-1, which is a block diagram of the possible position information loops of the system. For the sake of completeness, this block diagram uses a remote site that has the ability to receive telemetry data as well as tracking and voice communication information. It is also assumed that the remote site is an "A" Station, i. e., it has command capability. For any site that does not have either one or both of these abilities, the block diagram may be simplified by deleting the appropriate loop.

Data Received. There are three types of data which are received by the remote station. They are as follows:

- a. Tracking Data - This is the most important position information available concerning the flight. It may consist of a



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Figure 4.5.2-1 Position Information Flow

combination of range, range rate, angle, angle rate data, azimuth and elevation.

- b. Telemetry - The main source of position information available from the telemetry is acceleration data. Depending on its accuracy, this information may or may not be used, along with the tracking data, to determine the vehicle ephemeris. The other main source of position data available is the Gemini on-board radar. Since the rendezvous is primarily an astronaut responsibility, this data will be used as backup and for collision avoidance.
- c. Voice Communication - Voice communication will provide only the gross information about position that the astronaut may relay. This may have some limited use during the final stages of rendezvous.

The three separate areas of information are received at the remote site, where they may be processed, and then relayed to the IMCC. The question then arises; "what type of processing may be done at the remote sites?" This determines the type and quantity of information that will be sent to the IMCC. The type of processing has been separated into four categories which will be discussed below.

#### Processing at Remote Sites

- a. Necessary Processing - The minimum processing possible (relative to position information) at any remote site must be sufficient to allow the sensor to search and lockon to the vehicle, and to format the data once it has been obtained. The reason and necessity for the search and lockon processing is evident. The format processing is necessary to ensure that the data arrives at the IMCC in recognizable form. The raw data from the remote site is of no value unless it is properly labeled. If the remote site had only the above-processing capability, it could merely send the raw data and enough information about signal strength, etc., so that the IMCC could calculate the accuracy of the data. Because of recognized communication limitations, only a portion of the tracking data should be relayed to the IMCC.
- b. Desirable Processing - Accurate tracking information can be obtained even without relaying all tracking data to the IMCC.

This can be ensured by some additional on-site processing. The raw tracking data can be smoothed by some minimal on-site processing. In addition, the accuracy of this data may be computed at the site. This technique has the advantage of using all the information available at the site to provide smoothed, accurate data for the IMCC. This would relieve the communication link of a heavy burden and provide more room for telemetry information.

- c. Possible Processing - One of the tasks that could be performed at the remote site is the acquisition program. The remote site processor could use elements provided by the IMCC to provide sufficient acquisition data to track the vehicle.

The remote site processor could also provide an ephemeris extending to the next site. This would provide a back-up to the IMCC ephemeris computation and aid in the acquisition of the vehicle by the next site.

Another possible function that could be performed at the remote site involves a more sophisticated computer. This function could involve the calculation of abort and alternative mission profiles. This function would only be done at an "A" station. The station would then be able to act independently of the IMCC in the event of an emergency occurrence. Such a requirement would be necessary if a communication black-out situation existed. It would also act as a backup for the contingency computation normally performed at the IMCC.

- d. Undesirable Processing - It is unwise to perform extensive orbit computation or differential correction at the remote site, because the limited information available there is subject to large bias errors. This could cause long-range predictions to have large errors.

#### Position Information Flow at Remote Site.

Some small portion of the telemetered position information may be routed to a remote site display. This information and, primarily,

instructions from the IMCC will be used to provide normal mission recommendations to the astronaut. If the remote site were equipped with the ability to calculate contingency information it could relay this in the event an emergency arose. The smoothed tracking data, its accuracy, and the other position data is relayed to the IMCC.

#### Processing at IMCC

The information received at the IMCC is used to generate the vehicle ephemeris, the orbital elements, and the recovery or impact information. The details of this computation are discussed in Sections 4.5.2.2 and 4.5.2.3 of this report. If there is no facility for acquisition computation at the remote site, this function will also be performed by the IMCC computer. The IMCC will also have the prime and perhaps the only responsibility for computing alternate missions and abort trajectories.

Position Information Flow at IMCC. The ephemeris computation will be retained at the IMCC and used to provide the position status of the vehicle. The same may be said about the orbital elements. These may also be relayed to the remote sites if they are able to do their own vehicle acquisition computations. The elements will also be used to compute the orbit lifetime of the vehicle. This information will be considered part of the standard mission information, and may be sent to the astronaut, if desired. The recovery information is sent to the recovery forces. Some elements and position information will be displayed at the IMCC.

If the acquisition calculations are performed at the IMCC, they in lieu of orbital elements will be relayed to the remote site.

The alternate and abort mission profiles will always be kept current and ready for transmission to the vehicle in case of an emergency.

The normal mission recommendations will be generated at the IMCC by the cognizant personnel. Their decisions will be based on information generated by the computer in display or hard copy form, and predetermined mission plans. The requisite recommendation will be relayed to the astronaut.

Block Diagram. The block diagram in Figure 4.5.2-1 shows the possible paths of position information flow. In some cases, where a function could be performed at either the remote site or at the IMCC, both paths are included. For example, the vehicle acquisition information is shown to be calculated at both sources. When it is decided which location is the most efficient, the other path may be deleted. The same situation occurs for the abort and alternate mission paths. If the remote site has a computer of sufficient complexity, both paths will be retained; if not, only the path from the IMCC will exist. All normal position information paths are indicated by solid lines and all emergency paths by dotted lines.

#### 4.5.2.1.2 Smoothing and Selection of Observational Position and Velocity Data

The high repetition rates of electronic sensors has several implications:

- a. An enormous amount of positional data accumulates in a short time.
- b. Each datum is highly correlated with adjacent data because the repetition rate is much higher than the orbital frequency or the Earth rotation rate.

Noise frequencies, however, are usually greater than 1 cps. This means that the signal is easily distinguished if data received over more than a few seconds are examined.



Previous Experience indicates that for long-term predictions (significant fractions of a revolution) of space vehicle positions, it is not necessary to use more than a dozen points per pass. This corresponds to about a point per minute for a zenith pass for Gemini missions. During the translunar trajectory of Apollo when the rotation of the station around the Earth limits the pass, the dozen points can be spaced over several hours. Short-term predictions will be discussed later.

It is, therefore, possible as well as desirable from the standpoint of communication loads, to reduce the amount of data on position and velocity transmitted to the IMCC. This can be accomplished in several ways.

The simplest process is to select data at the needed rate. This selection, however, has the disadvantage of transmitting all the noise in the transmitted data.

Another possibility, because of the correlation of the data, is to transmit only differences from a fixed quantity (e.g., the first observation) rather than the whole numbers. This does not relieve the communication load significantly.

Other things being equal, it is better to smooth the observational data on-site before transmission. This results in increased accuracy and also in compression of the data. For completely redundant data, the error decreases as the square-root of the number of measures averaged. The same law applies to data smoothed by, say, an appropriate polynomial fit. The law cannot be extended to an indefinitely large number of measures because the noise will also become correlated when its characteristic frequency is approached; thereafter, no improvement in accuracy is possible.

The Millstone Hill Radar Site reads out smoothed points every 6 seconds. Dr. Nesbeda (RCA, Burlington, Mass.) has examined some Millstone tracks on Earth satellites and has found 6 seconds to be nearly optimum smoothing interval. The note on "Goddard Processing" also mentions 6 seconds as the interval of the tracking data on Mercury.

It is recommended that data from a Gemini pass should be smoothed to give, for approximately every 6 seconds of tracking, one set of data (e.g., position with respect to the station and range-rate). This smoothing should be done by the remote site data processor to reduce the communication load. The remote site data processor need not transform the satellite positions to inertial reference axes. It should not attempt to produce orbital elements. The IMCC is best equipped to produce elements by further smoothing, in the form of weighted least-squares differential corrections, using data from all sites and, possibly, from the vehicle.

The recommendation on smoothing does not eliminate the possibility of the selection of observations. First, very discordant data can be eliminated in the smoothing process. For example, all data, deviating more than three standard deviations from the polynomial, could be rejected and the polynomial refitted over the remaining data. Secondly, the exact repetition rate for tracking still must be chosen. This frequency should be limited by the characteristic frequency of the noise in the tracking data. Below this frequency, a compromise can be made between accuracy and data load. Thirdly, tracking need not be continuous throughout a pass. If it is deemed desirable to maintain the same smoothing program and repetition rates for higher missions (e.g., Apollo Earth Orbits), processing and trans-

mission of tracking data could be interrupted during the pass to give, perhaps, three arcs: near rising, near zenith and near setting.

The final consideration of smoothing concerns short-term prediction. The smoothed function generated (e.g., a polynomial) can be used for extrapolation as well as for accurate interpolation. Provided the amount of extrapolation does not exceed in magnitude the time span of data used to generate the polynomial, the errors introduced will be within an order of magnitude of the errors in the smooth (interpolated) points. These errors, of course, depend on the choice of function. For instance, it is possible to fit a great circle, centered on the sensor, to the angle data in part of a pass, but not, in general, to the whole pass. For functions to describe a whole pass, it is desirable to transfer the coordinate origin to the center of the Earth (except for Moon-centered orbits). Then, it is also possible to introduce the dynamic equations of free fall to improve the model. The last computation, however, may well exceed the capacity of the remote site data processor. Thus, the tracking data, not necessarily in excess of the 10 points per minute suggested above, must be sent to the IMCC. Shorter term extrapolation can be used by the site to keep the antenna locked on the vehicle.

#### 4.5.2.1.3 Accuracy Evaluation

It would be desirable to send some accuracy information along with the position data. It is from this data only that the IMCC can determine the relative merits of slightly ambiguous information emanating from two sites. It may be used also to determine the safety envelope for collision avoidance and other performance parameters of the system.

The accuracy of the data can be determined by such things as signal strength, signal-to-noise ratio, elevation angle, environmental conditions, and instrument accuracies. For example, when a vehicle is "visible" to a remote site at a greater distance, traversing a path close to the horizon, the station probably cannot establish an accurate track.

This sort of information will enable the IMCC to place some weighting factor on the data relayed by any remote site. These data will be used in conjunction with the IMCC's overall knowledge of the station accuracy to provide input for the computational sequences. This accuracy data will be relayed for every pass as will the information it influences. For instance, the sources that contribute to the errors of angle information are completely unlike those that contribute to vagaries in vehicle acceleration telemetry.

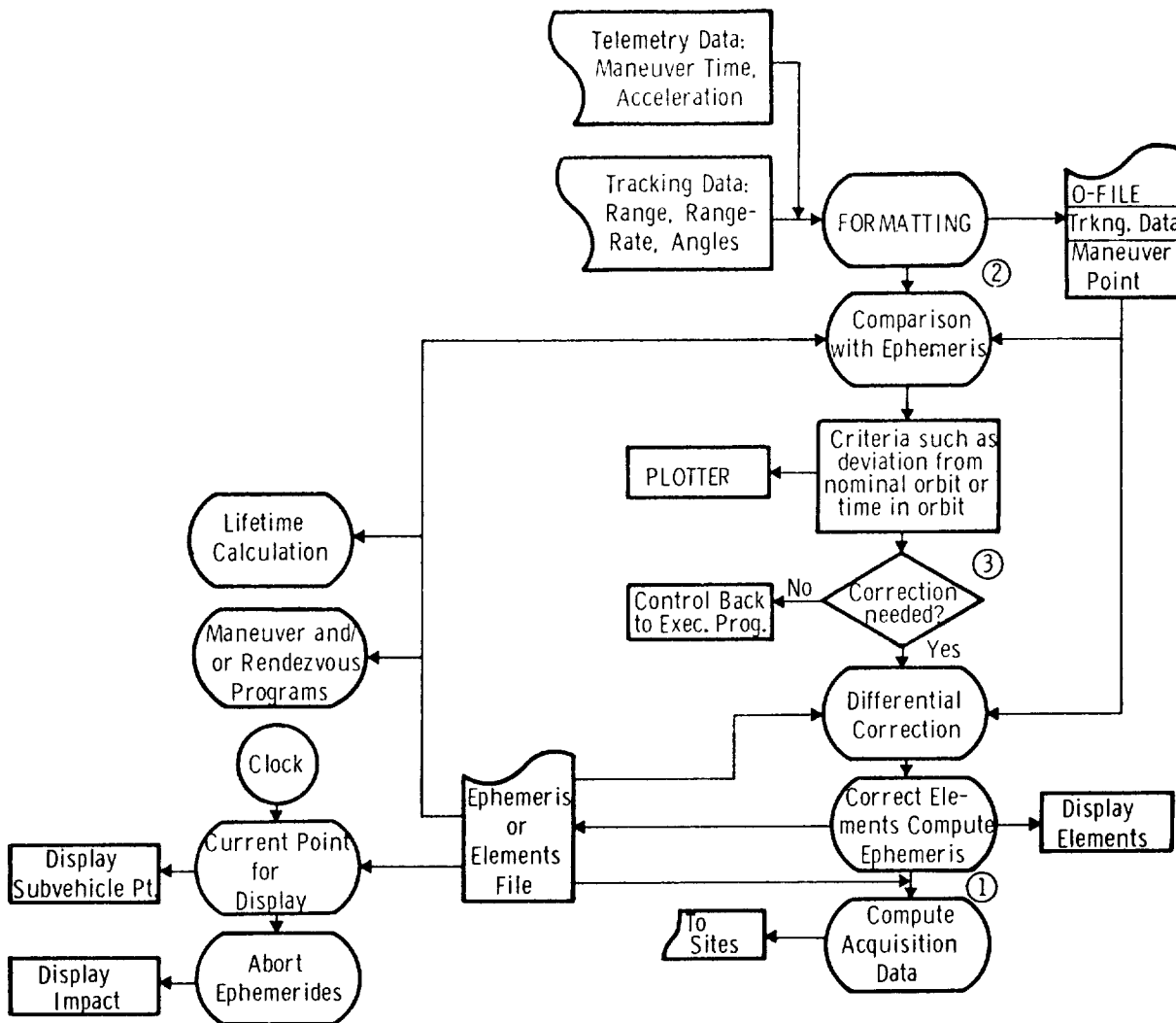
A great deal of this accuracy information can be estimated during simulation exercises, and from observations of other satellites.

#### 4.5.2.2 Ephemeris Computation

An ephemeris is a table of the coordinates of an orbiting body tabulated at constant intervals of time. It is necessary to maintain such an ephemeris of the Gemini and Agena vehicles to be able to train the antenna of each station of the communication and tracking network (in the proper sequence) on the spacecraft and to predict future spacecraft position so as to schedule events such as rendezvous or reentry. The flow diagram Figure 4.3.2-2 shows a computing scheme at the IMCC to generate ephemerides. The central column shows the routines necessary for the maintenance of the ephemerides. These will be discussed further below. The other functions which require the ephemerides or elements are shown on the left side of the figure. They will be discussed briefly in paragraph 4.5.2.3.

The raw observational data are presumed to be available from a buffer where they have been placed by a discriminator which has identified them as tracking information, upon receipt. A special type of information, which may be of value, is the time, position and velocity achieved during a maneuver. That is, the maneuver position and velocity may be used, as may the observations, as conditions which the true orbit must satisfy.

The observational data must, at some point, be put into a uniform



## NOTES:

Vertical arrows indicate program flow. Program should loop back after Differential Correction to check validity of new elements by comparison with observations.

- ① Executive Program can enter or interrupt at this point.
- ② Executive Program can enter or interrupt at this point. Validity of message format should be checked in Formatting Routine.
- ③ This decision, based on the position criteria, can be overridden by the Executive to permit corrections before accurate maneuver calculation, etc.

10099-P

Figure 4.5.2-2 IMCC Computations for Tracking Reduction During Non-Powered Flight

format and stored in an observation file. This file can then be used when a differential correction is necessary. After a maneuver has been executed, the observational material on that vehicle can be dumped (or deleted) and a new file started.

The first use made of the observation is to test whether the orbital elements still represent the true orbit to sufficient accuracy. If this testing is not always possible at the time the observation is read from the buffer, a tag must be provided to show that the testing has occurred and that the observation is valid for that vehicle. The criteria for this test will be discussed in paragraph 4.5.2.2.3; the other use, differential correction, is discussed in paragraph 4.5.2.2.2.

The result of the differential correction is a set of starting conditions for a new ephemeris. These may be simply the position and velocity at some epoch or a set of orbital parameters which are mathematically equivalent thereto. The integration of the ephemeris is discussed in paragraph 4.5.2.2.1.

Finally, an ephemeris must be produced for each sensor site to enable that site to acquire the vehicle on subsequent passes. These ephemerides are given as station-centered acquisition coordinates.

#### 4.5.2.2.1 Orbit Models for Gemini

The question of the representation of an orbit by a mathematical model involves three questions:

- a. What forces are included?
- b. What quantities are integrated?
- c. How is the integration performed?

The last two questions are related and will be discussed together.

Forces. The forces considered in the model should, of course, be those which will affect the position of the vehicle significantly. This assumes that the attitude of the vehicle can be determined from telemetry (and/or voice) and thus need not be integrated. "Significantly" may be defined as exceeding the accuracy requirement (capture volume) of rendezvous. The prime candidates for consideration are the first two items in the following list:

- a. Oblateness: The number of harmonics of the geopotential which are significant must be determined.
- b. Drag: The best atmosphere model, possibly including diurnal (longitudinal) affects, should be used.
- c. Lunar and Solar gravitational attractions have small effects near the Earth.
- d. Solar radiation pressure has an effect of about 1% of the drag at 150 nautical miles altitude.

Integrands and Integrals. The choice of integrands should not be seri-



ously affected by the choice of elements for display. This choice is, however, affected by the integration method; that is, whether numerical or analytical integration is used. A tentative assumption of numerical integration is made for the following reason.

The main disadvantage of numerical integration (special perturbations) is its consumption of computer time in establishing points in the orbit between observations. That is, the orbit is tied together by integration at a uniform (for circular orbits) time step. Position calculations must be performed for each step. This disadvantage is lessened for Gemini, however, since position and velocity will be needed continuously to calculate abort trajectories.

Another disadvantage of numerical integration is a faster error buildup due to rounding and truncation of the integration formulas at each step. For Gemini, this limits the period between updating of the ephemeris. This period should be much greater than that required to compute the rendezvous maneuver so that sufficient accuracy can be maintained from the update epoch until the actual rendezvous time.

The main advantage of special perturbations is that it permits simplicity of formulation. The simplest procedure would be to integrate the total acceleration of the vehicle to obtain position and velocity. This, however, would require small step size and double-precision calcula-

tion to maintain sufficient accuracy. The basic difficulty in this direct integration ("Cowell's Method") is that the integrand, the acceleration vector, includes the large central attraction of the Earth. If this term can be removed, the integration step size can be increased; thus rounding error is decreased and accuracy can be maintained longer without double precision.

Since integrals exist for the motion under central acceleration only, the perturbed solution can be obtained by the method of variation of parameters. The parameters chosen to describe the Gemini orbit should not be singular for circular orbits. Thus, the argument of perigee must be replaced.

The integration of a low circular orbit can proceed at steps of about three minutes, but it may be desirable to decrease the interval to accommodate a slightly smaller interval required for:

- a. Acquisition coordinates
- b. Abort calculations
- c. Display update

Since round-off error increases with the number of steps, the actual step should be near the optimum, the crossover with truncation error, which increases with step size.

One variation-of-program computes one Runge-Kutta integration step

(actually four position calculations) in one-half of a second of IBM 709 time. Making the very conservative assumptions:

- a. IBM 709 and Runge-Kutta
- b. Two minute steps or about 45 steps per revolution
- c. Four iterations for each correction
- d. Observations from two orbits
- e. Prediction over two more orbits.

Then each correction will take four minutes. Generation of acquisition coordinates, abort trajectories, etc., will take less than this amount of computer time.

The elements displayed need not be the same as the parameters in the program. They can be generated directly from the parameters in any form desired. Since no computation is performed with the display elements, singularities are no problem. For instance, argument of perigee can be displayed even when very inaccurate.

#### 4.5.2.2.2 Differential Corrections

Differential correction processes are the most effective means of improving the knowledge of the elements of a ballistic orbit. The differential correction formulas are also useful for error analysis.

The basic formula uses the total differential of the observed quantities,  $\theta_i$ , with respect to the six orbital parameters,  $p_j$ , as independent variables:

$$\Delta \theta_i = \sum_{j=1}^6 \frac{\gamma \theta_i}{\gamma p_j} \Delta p_j$$

This "equation of condition" contains, of course, only the first order forms of a six-dimensional Taylor series. It is generally better to ignore the higher order and to obtain the solution by iteration. Fortunately, the limits of convergence are wide enough so that the nominal or design elements can be used to start the process after injection or a maneuver. This eliminates the need for programs to obtain elements from observations alone (these programs are time consuming and usually need to be followed by the differential correction immediately in order to obtain sufficiently accurate ephemerides). The limits of convergence of the differential correction process are probably much wider than the divergence which range safety, for instance, will allow.

The observed quantities can be:

- a. Range
- b. Azimuth
- c. Elevation or zenith angle
- d. Right ascension or hour angle
- e. Declination
- f. Range rate
- g. Rates for any of the above angles
- h. Direction cosines, etc.

It is best to treat each observed quantity as a separate condition of the orbit and not to combine the quantities to obtain others. Since some types of measures (e.g. angles) are less accurate than others (e.g. range), the combination of such measures (e.g. into a position vector) will degrade the accuracy of the best component. The optimum correction can be obtained by combining the equations of condition (presumably more than six) by a weighted least-squares process. In this process, each observed quantity contributes to the solution in proportion to its accuracy. It is more difficult to establish the weights of derived quantities. If the reciprocals of the variances in each observed quantity are used as weights, the differential correction can, with no extra computation, supply the variances (and covariances) of the derived elements. These may be used to compute the accuracy of future positions. The constant of the equation of condition,  $\Delta \Theta_1$ , is obtained by subtracting

from the observed quantity, the same quantity it would have been had the elements been correct. This difference is known as a "residual". The object of the weighted least-squares differential correction process is to reduce the weighted square of the residuals to a minimum.

The partial differential coefficients in the equations of condition may be determined by formulas which are the analytical derivatives of the orbit formulas. In practice, the Keplerian orbit formulas are sufficient, since the differential perturbation effects are of second order.

4.5.2.2.3 Correction Criteria

The correction process need be initiated only when the observations indicate an intolerable departure from the elements in the computer. Of course, the standard of tolerability may change during the flight. It will, therefore, be wise, unconditionally, to correct the orbital elements of both vehicles before the rendezvous computation. Otherwise, the correction is conditional on criteria upon the observations.

If the first vehicle is assumed to have just been injected into orbit, the nominal elements have been read into the computer and an ephemeris has been generated, acquisition coordinates have been sent to the down range stations and then the observations begin to arrive, when should correction be performed?

One correction criterion which may be used to trigger a correction is the absolute magnitude of the individual residuals. For instance, the requirement may be that any position component must be within 10 nautical miles of the computed value. Therefore, when an azimuth measure,  $A$ , arrives, it is tested to see if the linear displacement,

$$\rho \cos h \Delta A \leq \text{nautical miles}$$

where  $\rho$  is the range from station to satellite and  $h$  is the elevation angle. A similar criterion can be designed for velocity data.

Such criteria, however, allow any bad piece of data, perhaps corrupted in transmission, to trigger a correction. If this is undesirable, it is necessary to determine if there is a trend in the residuals. This is easy to see when the residuals are plotted against time, but it requires a curve-fitting program to automate this function.

A quicker way to establish a trend is to examine the mean square of the residuals. Here, the computer must wait until a minimum number of residuals has accumulated and then test their mean square against a limit. This limit should be less than the square of the displacement permissible since the early observations, which should generally be close to nominal, will tend to keep the mean square low. When a correction has been completed, the mean-square deviation should be recomputed from new observations as they arrive.

When a maneuver is executed, the design orbit elements can be used to start the process again. The new observations will be used to recompute the mean-square deviation.



#### 4.5.2.2.4 Acquisition Coordinates

Acquisition coordinate computation involves only a subtraction from the geocentric position vector of the station coordinates relative to Earth. From the difference, the required polar coordinates are easily obtained. The program only produces those points at which the vehicle is visible to a particular station and addresses this message to that station. If the station needs only these coordinates at the integration step interval, no further computation is needed.

If acquisition coordinates are needed at special times, such as at highest elevation, these can be calculated from the elements or can be interpolated. A modest amount of scheduling may be needed to track both vehicles when they are close together but not yet in the same orbit.

It is possible to transmit the elements for the approximate time of the pass to the station. Then the station could generate its own acquisition data. The generation of the coordinates from these osculating elements requires a moderately sophisticated computer.

#### 4.5.2.3 Related Functions

Several additional computational tasks have to be performed that are not ephemeris calculations. The maneuver and rendezvous portions of the flight have some unique computational requirements. These two functions introduce a discontinuity into the ephemeris and require some special techniques. Virtually, this involves the calculation of a new flight path starting at the point at which the function took place.

The lifetime of the vehicle is one of the first tasks that must be performed by the IMCC. The results of this computation indicate whether the vehicle has been injected into an orbit that will be compatible with the mission requirements. If not, the computer indicates the need for an orbit correction or the start of an abort action.

The other major, related function that must be provided by the IMCC computer is the information to drive the position displays. The two major displays will be the orbital element display and the subsatellite track. The orbital element display will consist of an alphanumeric digital output of the parameters most meaningful to the users. The subsatellite track will give the locus of the point on the earth below the vehicle. This locus will be traced on a projection of the earth. Its primary function will be to give gross positional data to the personnel in the MOCR. It will also indicate which stations are in contact with the vehicle.

#### 4.5.2.3.1 Orbital Element Display

The element display is the least critical of the position data recorded. It can be displayed as an alphanumeric digital output and need not be updated very often. The display is intended to give only the necessary orbital parameters and will not be used for specific mission recommendations. The display is intended to be informative, and therefore, should give orbital elements familiar to everyone. That is, these displayed elements need not be the same ones used in differential correction. Of the six standard elements; semi-axis major, eccentricity, inclination, longitude of ascending node, argument of perigee, and some measure of time, only the first five need be displayed. The measure of time is unnecessary since this will be indicated by the subsatellite track. In addition, some other parameters, that are redundant but informative, may be displayed. These would include perigee height, apogee height, and period. For the Gemini mission, there should also be some display detailing the distance between the two vehicles and the rate of closure of this distance.

The personnel at the IMCC will have the final choice of the exact elements to display. The computation of the elements involves a simple transformation from either the differential correction elements or the ephemeris.

#### 4.5.2.3.2 Subsatellite Track

The subsatellite point is the point on the surface of the earth directly under the vehicle. The subsatellite track is the locus of these points.

The prime use of the subsatellite track computation is to drive the main display. The track will be shown as a line traversing a projection of the earth. This display also gives some auxiliary information, such as, what remote sites are in contact with the vehicle.

There are two possible methods of generating the subsatellite track; from the ephemeris, and by using the orbital elements.

- a. Subsatellite Track From Ephemeris. The ephemeris computation generates the radius vector from the center of the geoid to the vehicle. It is an extremely easy computation to generate the subsatellite track from the ephemeris data. The only undesirable feature is the fact that the track would not appear as a continuous path on the display. The subsatellite points would appear only at the interval of the integration step. For example, if the integration step is 2 minutes, then the subsatellite point would only be updated every 2 minutes. However, the computer calculates these subsatellite points very accurately.
- b. Subsatellite Track From Orbital Elements. The orbital elements could also be used to generate the subsatellite track. This method would not be quite as accurate as the ephemeris method but accurate enough for its intended use. The method also involves some additional computation. The lessened accuracy and additional complexity are due to the fact that truncated series must be used in the computation. The bonus feature of the method is the fact that the subsatellite track may now be plotted as a continuously increasing line on the earth projection. This is due to the fact that the orbital elements can be used to determine the angular rate of the vehicle. There are discontinuities in this method also, due to the fact

that the orbital parameters are updated by differential correction periodically. The difference in the elements will be usually so small that the changes will not be noticeable.

Some combination of the two methods appears to be the most informative ground track for the display. The use of the velocities generated by the ephemeris or the rate calculated from the elements and a check each time a new point from the ephemeris is received, would be acceptable schemes.

#### 4.5.2.3.3 Abort Ephemerides

The abort ephemerides for the Gemini mission can largely be predetermined and introduced to the computer as input. This would reduce the real-time computation load on the computer and yet permit easy access to the necessary information. The down-range distance and the cross-range distance may be formed as a table which is a function of altitude and latitude. Therefore, if an emergency occurs, the probable impact point can be obtained quickly by a table lookup. It does not matter if the emergency requires an immediate action or whether the action will be initiated at some time later in the orbit to bring this impact point into some predestined area.

Once the abort has been initiated, the new data received from the remote sites will allow the impact point to be updated. In addition, the impact point, for the case of emergency procedures, will be constantly recorded and displayed at the IMCC. This is necessary so that the recovery forces have some gross target area until the more specific data is computed.

4.5.2.3.4 Maneuver and Rendezvous

Maneuver. The IMCC computation is relatively unchanged for a maneuver. The vehicle's ephemeris is constantly available at the IMCC. It is on this ephemeris that the maneuver may be based. The only requirement is that differential correction be initiated immediately before the maneuver so that the best elements possible are available. The computational facility will also indicate the impulse required to modify the ephemeris so that it performs its desired objectives. It will perform this task by determining the new nominal position and velocity to achieve this ephemeris. The required maneuver can then be determined. This nominal position and velocity will then be used to calculate the nominal orbital elements for the initiation of a new ephemeris. The procedure will then revert to the same one as before the maneuver. The ephemeris will be calculated and the differential correction procedure continued.

Rendezvous. During rendezvous, the main computational involvement is the fact that there are two vehicles which must be tracked and for which ephemerides must be generated. It is believed that the prediction techniques are sufficiently accurate and rapid enough that there will never be the need for the computation of both vehicles to be performed at the same time. The actual function of rendezvous is the

responsibility of the astronaut and, therefore, the IMCC computational facility has no direct responsibility.

The performance after rendezvous will be exactly the same as that mentioned above for the maneuver. The nominal elements will be used and a new ephemeris and differential correction started.



#### 4.5.2.3.5 Orbit Lifetime

The orbit lifetime calculation need not be an accurate one. It is only necessary that the vehicle have a lifetime that exceeds, (with some safety factor), the intended duration of the mission. It is of no consequence to calculate any further than this mission requirement.

The lifetime data is generated from the orbital parameters, for example, perigee height and eccentricity. It is imperative that the lifetime be calculated early in the first orbit. This is necessary so that the astronaut may make corrective maneuvers or initiate an abort sequence if the vehicle is going to decay rapidly.

It is necessary that the safety factor mentioned be large enough so that no part of the mission is attempted during a period of high decay.

## SECTION 5

### INFORMATION FLOW PLAN

#### 5.1 GENERAL

To determine the design plan of a complex system, development of an overall approach and a set of detailed analytical techniques which are specifically appropriate to the particular design effort, is required. In approaching the GOSS information flow plan, particular importance has been attached to structuring the design effort so that the iterative nature of the design process is explicitly recognized, as is the need for continually improving both the overall approach and the specific analytical techniques.

##### 5.1.1 Presentation of Study Output

It is most appropriate that results generated in this study be displayed in the same form that the ultimate final output will take. For each report of the design effort, an attempt will be made to do this. Those specific GOSS results which have implications for long lead-time items (high speed data links, for instance) or which require NASA decisions to resolve design impasses, will be coordinated also at more frequent intervals, between reports. Attached are two charts which summarize the current study approach, Figures 5.1.1-1 and 5.1.1-2.

Considerable thought has been given to the problem of how best to present the final output of the study. Serious attention will be directed to

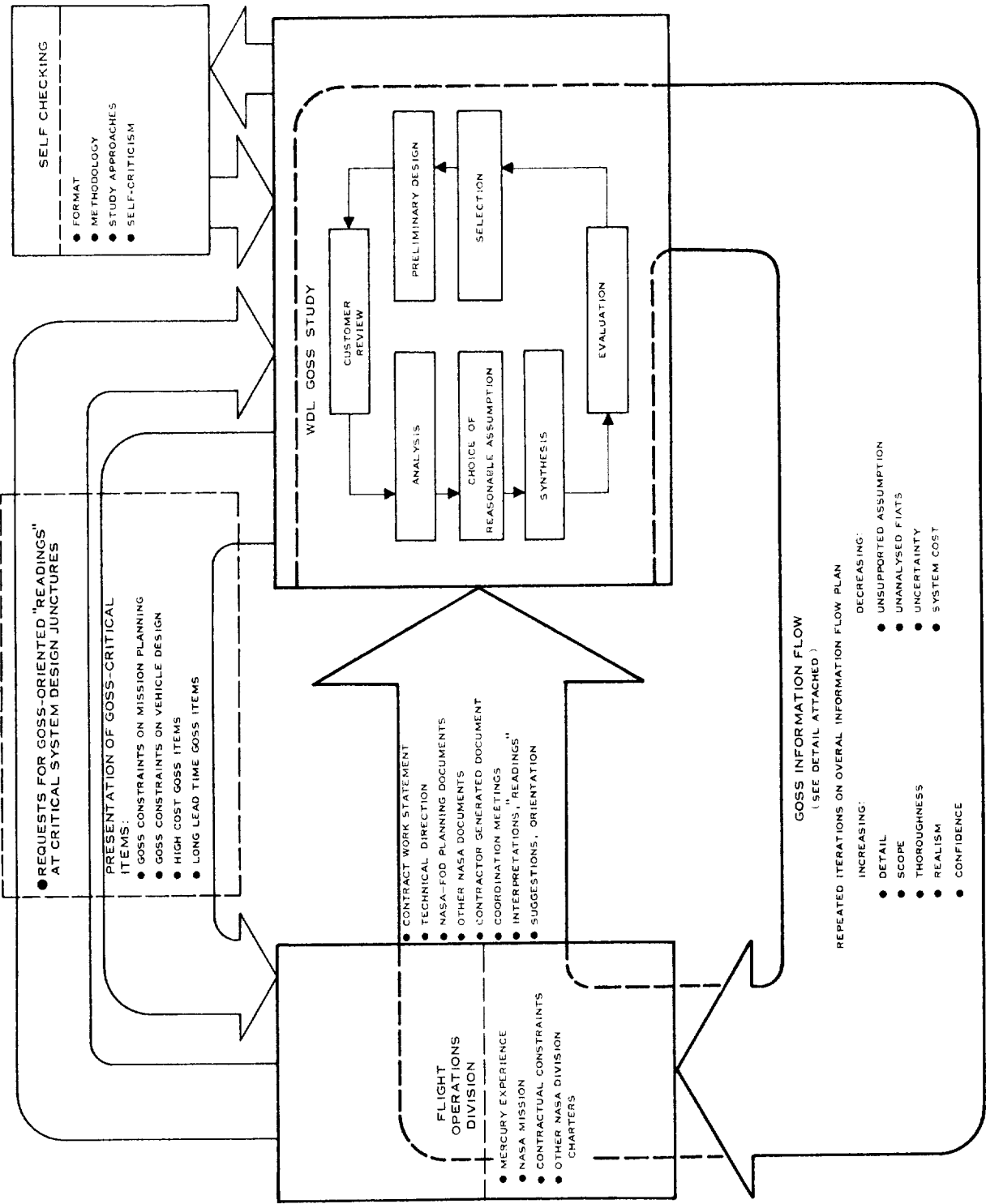


Figure 5.1.1-1 GOSS Design Flow

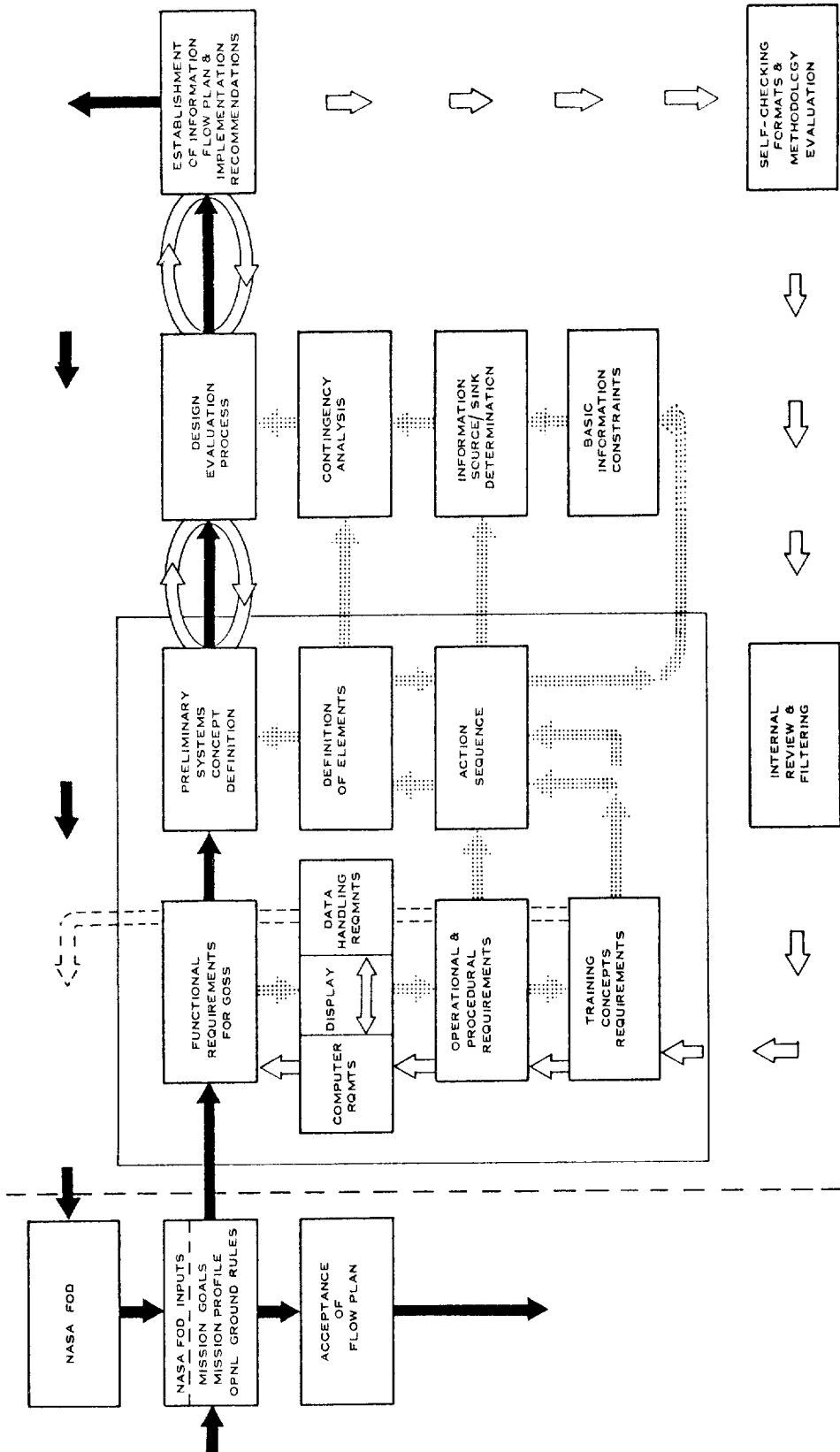


Figure 5.1.1-2 Basic GOSS Flow Plan Design Phases

this end, as the design takes shape. As far as scope is concerned, the output of this study effort should be a set of information flow criteria, presented in sufficient detail to enable the writing of systems and performance specifications. The initial attempts to cast the information plan into a semblance of its final form will occur during the evaluation phase as part of the testing of the adequacy of the tentative flow plans. After more detailed consideration of this matter, the proposed format will be discussed with Flight Operations Division personnel before it is finalized.

### 5.1.2 Development of Design Tools

It appears, at this time, that the straightforward approach to developing the GOSS Information Flow Plan is that of "design-evaluate-redesign" rather than that of attempting to divide the flow into small nets, or loops, to be developed separately and later integrated.

This means that an attempt will be made to have an overall Information Flow Plan available at every stage of the study effort. As the study progresses, the level of detail will increase, together with the scope and degree of specificity, realism, and confidence. Uncertainties and omissions in initial estimates will be resolved as the work load permits, and as new and revised inputs dictate. An attempt will be made to justify all critical assumptions on, at least, a qualitative basis.

Although the design-evaluate-redesign method is the most straightforward and logically-appealing technique available for a system with the structure of GOSS, there are study-phase interactions and other procedural complexities which must be recognized. For example, initial design must be such that the final functional and operational concepts of the GOSS system are "in the back of the designers' minds" at each stage of design and redesign, however vague and incomplete these concepts may be at any given time. The evaluation must not cause the design process undue delay, and yet it must be sufficiently realistic to

make each "cut" at the system design in much the same manner as the system itself will be exercised in operation. This may require that new evaluation techniques be developed in parallel with the main design effort, as more realism and depth are demanded in the evaluation phase.

Because the evaluation phase should not unduly delay the synthesis effort, it seems advisable that speed of performance be given serious consideration by directing attention to the development of a computer model of the flow.

First, however, a certain amount of preliminary analysis will be required to determine to what degree such a simulation should be carried to obtain useful results, whether this level of effort can be supported within the current scope of WDL responsibility, and whether some simpler types of models might serve the purpose just as well.

Since any reasonably complete simulation model will contain a complete description of the modelled system in some more or less accessible form, such a design tool could also serve as the nucleus of the overall information flow plan. In this capacity, it would be bolstered by an array of "cuts" through the system to test the influence of a variety of parameters. Each "cut" would be made with the needs of a specific type of user in mind; e. g., equipment, specification writers, etc.

### 5.1.3 Adequacy of the Plan

All of the preceding sections of this report are aimed at producing the information flow plan to be presented in this section -- the "job" is to produce the plan, but how can one measure the adequacy of this job? At what point in time can one cease to develop the plan and commence to implement it? How can one determine when a "final" or "best" plan has been achieved?

The final plan can be approached from many directions, along many axes -- many "cuts" at the plan may be taken. But all these axes should converge to a common point: the desired information flow plan. If development of the plan is progressing simultaneously along these many axes, convergence (i. e., the final plan) will be manifest in the increasing similarity of developments as they all move closer to the origin of their axes. These "axes" are dimensions of the flow plan development, and as used here, will be developed by:

- a. System segment
- b. Function
- c. Position (within IMCC and outside the IMCC)
- d. Source
- e. Sink
- f. Phase
- g. Time interval
- h. Link
- i. Contingency class
- j. Information class
- k. Information characteristics



Although this list may not be exhaustive, it is sufficiently extensive to determine the state of completeness of the flow plan development.

## 5.2 LIFE SUPPORT SYSTEMS INFORMATION FLOW PLAN

Figure 5.2-1 shows a concept of one flow of information necessary to monitor the crew, biomedical experimentation, environment, and environment control system data. Stress has been given to the flow within the support area and MOCR, although the remaining parts of the system are shown for the sake of completeness.

The primary purpose of this diagram is to show the functional relationship between the support area and the MOCR. No attempt has been made to show the detailed readouts. Control functions necessary for data and display control also are not shown.

The primary assumption, by which this diagram was made, was that the detailed life support analysis will be done in the support area. Abstracted and irregular data will be presented to the console operators in the MOCR. The capability will exist also for presenting to these operators any additional information they desire.

The environmental control system, environment, biomedical experimentation, and crew data monitoring support functions were incorporated into the same support area because of their inherent functional relationships. However, the environment control systems status data was routed to the Gemini System Status Monitor console, and the crew biomedical and environmental data was routed to the Biomedical and

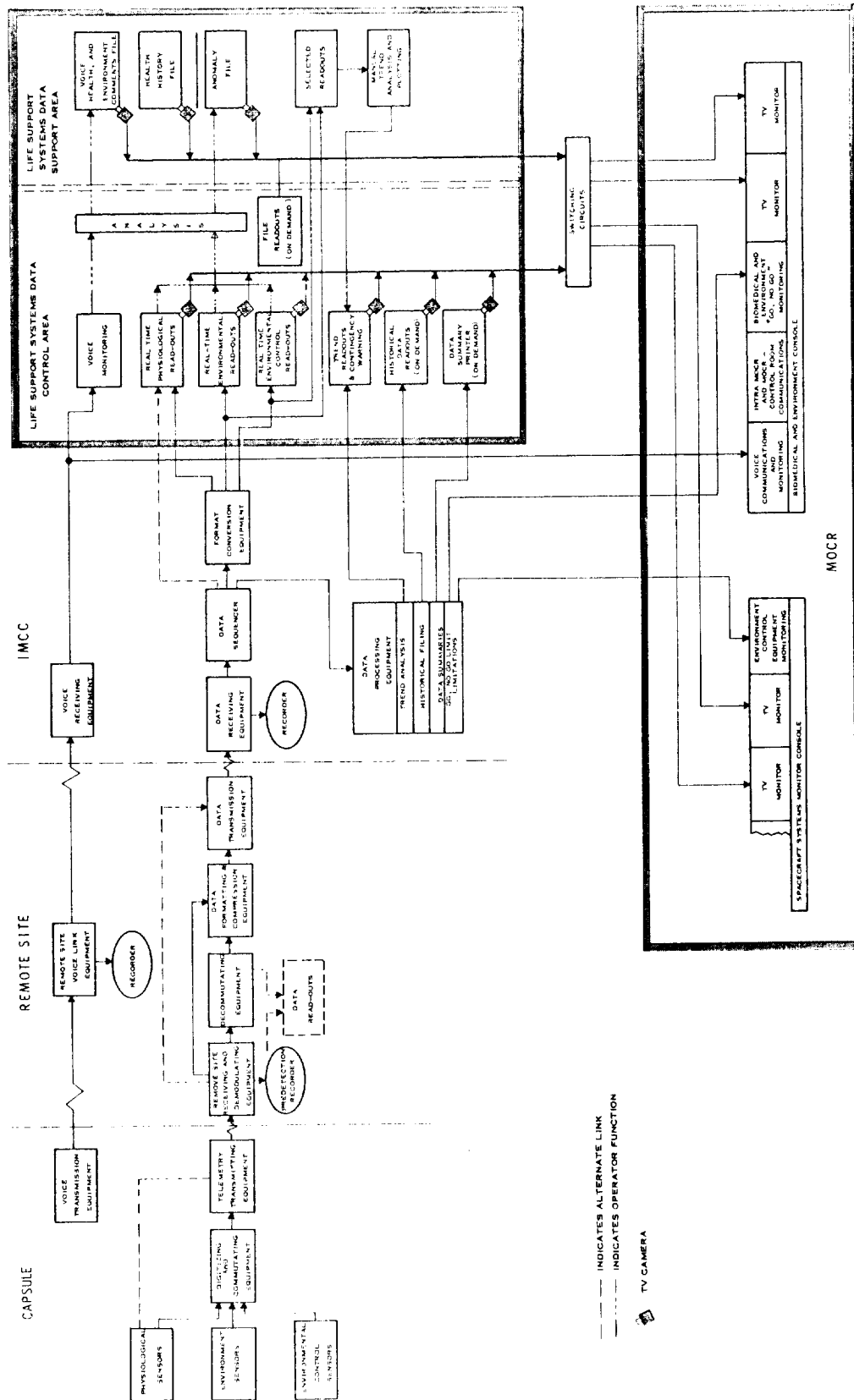


Figure 5.2-1 Life Support Systems Display Information Flow

Environmental Monitors console. This division of function within the MOCR seems the most logical.

The flow of information in the support area yields the flexibility needed for several types of missions. Both short - and long - mission monitoring data for both the Gemini and Apollo Projects and data for missions, primarily biomedical in nature, could be accommodated by this arrangement. It should be noted that each of the "TV camera" symbols on the drawing does not necessarily mean that a separate camera is to be used; rather, it means that cameras are to be accessible to information in more than one diagram box. For example, all of the file information might be grouped into one area having one camera.

## SECTION 6

### MANNING CONCEPT

The manning concept for Gemini GOSS is considered in two parts. The first deals with a manning concept for the IMCC which is further divided into the Mission Operations Control Room (MOCR) and support areas. The second deals with the manning concept for the remainder of GOSS including the remote site network, launch control, and recovery operations.

#### 6.1 IMCC OPERATIONS

The manning concept for the IMCC has been developed initially from a consideration of the functions to be performed during the various phases of an operation. Because of the time limitations in the preparation of this report, the concept is not based on the detailed flow of information required during these phases nor is it based on design considerations for processing such information, which simplify the personnel functions by displaying information only when needed and in a form permitting direct interpretation.

The IMCC manning concept, presented in this report, is conceived as having two levels: (1) activities which are directly involved in "normal" operations and (2) activities which support "normal" operations but do not require frequent action and are most often a requisite of "contingency" operations. The first level of activity is performed in the Mission Operation Control Room (MOCR); the second primarily in the adjacent staff areas. Criteria for locating activities in the MOCR are enumerated below:

- a. All functions and activities for the various phases of a mission which require direction or "final" decisions to be made by one person should be located in the MOCR. All personnel reporting directly to the Flight Director will be located in the MOCR. This is to insure that, during an operation, the Flight Director does not normally have to query individuals in remote areas but can directly query personnel in the MOCR. Staff area activities or functions would directly support personnel in the MOCR and

these, in turn, support the Flight Director. (In essence, the criterion is one of dividing functions and activities between systems and subsystems to restrict the number of people reporting directly to a flight director to permit a reasonable span of control, or a reasonable number of subordinates who report directly.)

- b. Functions or activities which require knowledge of the entire mission and the current status of the mission to interpret information concerning spacecraft systems and/or on-going events will be located in the MOCR. For example, the individual who normally has a responsibility to talk to the astronauts during an operation must be located in the MOCR. (This also serves to restrict access to those individuals whose duties may require that they talk to an astronaut during an operation.)
- c. Interrelated functions or activities which require interaction for a complete understanding of an event will be located in the MOCR. For example, during a mission it may be necessary for an individual to communicate directly with another performing a different overall function, but one that is related to the specific event which requires interpretation. This "cross talk," because of interrelated information and/or knowledge, thus constitutes a criterion for locating personnel together in the MOCR.

Staff area functions and activities will be grouped to directly support functions in the MOCR. For example, detailed data analysis activities for all elements of the life support function will be housed together to support directly the life support system activity in the MOCR. Staff functional areas will, of course, be interconnected via voice and video communication links since the same functional relationships and interactions exist as within the MOCR.

6.1.1 IMCC Tentative Manning. Based on the functions to be performed during a Gemini rendezvous mission, the following tentative staffing of the MOCR has been developed for control during Gemini flights (see Figure 6.1-1):

- a. Operations Director
- b. Network Commander
- c. Recovery Commander (located adjacent to MOCR)
- d. Flight Director
- e. Assistant Flight Director
- f. Operations and Procedures Officer
- g. Remote Site Coordinator
- h. Vehicle Systems Officer
- i. Vehicle Systems Status Adviser: Agena
- j. Vehicle Systems Status Adviser: Gemini
- k. Vehicle Communicator
- l. Flight Test Assistant
- m. Biomedical and Environment Monitor (Flight Surgeon)
- n. Flight Dynamics Officer
- o. Assistant FDO for Titan/Gemini
- p. Assistant FDO for Atlas/Agena

Each of these functional positions is discussed in the following paragraphs.

Operations Director: The Operations Director has overall responsibility for the conduct of all missions. He makes the ultimate decisions as to whether or not a mission will commence upon recommendations by such personnel as the launch conductor, recovery commander, senior medical officer, and flight director.

Network Commander: The Network Commander is responsible for operational control of the GOSS network. He is supported by the Remote Site Coordinator.

Recovery Commander: The Recovery Commander has operational control of all assigned recovery and directs recovery forces prior to and during a recovery operation. He is located in the recovery control center area of the IMCC and will have a staff to support him.

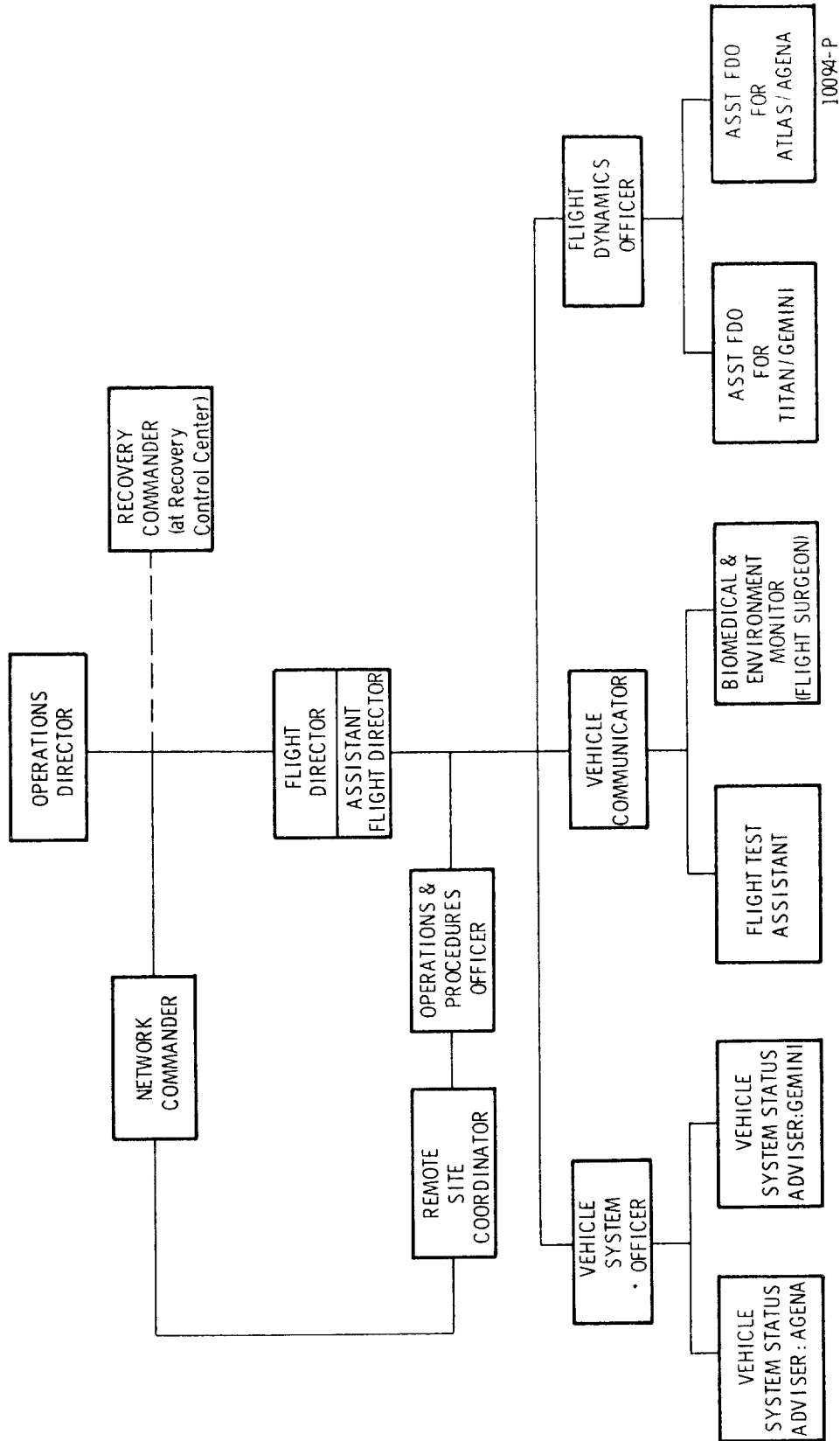


Figure 6.1-1 Tentative Operations Organization for MOCR



Flight Director: The Flight Director has the responsibility for detailed flight control of the Gemini and Agena vehicles from liftoff until conclusion of the flight, consistent with spacecraft crew responsibility. He is responsible for all decisions concerning the status of vehicle systems, aborts, maneuvers, and any communication to the vehicle whether in the form of commands to Agena or requests for actions to Gemini, in addition to the establishment and implementation of flight control procedures. He also assumes the duties and responsibilities of the Operations Director in his absence.

Assistant Flight Director: The Assistant Flight Director will act in the capacity of Flight Director during his absence. During other times, the Assistant Flight Director will assist the Flight Director in system check-out, GOSS exercise, network coordination, and operations procedures supervision. An example of his delegated activities would be the coordination of a reply to the vehicle in response to request for information. The Flight Director could delegate the coordination and construction of a reply to his assistant. The Flight Director would, of course, review and decide on the appropriateness of the reply.

Operations and Procedures Officer: The Operations and Procedures Officer will have responsibilities similar to those he has in Project Mercury. He will be responsible for the mission rules from a procedural point of view. Any change, modification, deletion, or addition to normal operating procedures will be coordinated with the Operations and Procedures Officer to insure uniformity and compatibility of operations. Any required interpretation of operations procedures or mission rules will be the responsibility of this officer. If there is more than one mode of "normal" operation, changes or switch-over will be coordinated by the Operations and Procedures Officer. He will advise the Flight Director on changes in the remote site net that would influence command and communication decisions. If the telemetered data system is programmable in the same sense that data arriving at the IMCC can be controlled in several discrete levels in terms of sampling rates, communication schemes, types and amount of data, etc., then the control over the

data will be coordinated by the Operations and Procedures Officer. Questions of priority, delayed transmissions, alternate routing and so forth, are under this control.

Since most of the decisions regarding operations and procedures affect the remote site network and GOSS communications, the Remote Site Coordinator position is directly related to the Operations and Procedures Officer.

Remote Site Coordinator: In addition to maintaining current status information on all GOSS elements, the Remote Site Coordinator is responsible for the ground-to-ground and space-to-ground communication links. As a backup to normally-automated procedures, the Remote Site Coordinator must schedule vehicle contacts, effect station switch-over when required, select a station for telemetry transmission when more than one station is receiving vehicle telemetry, implement changes in operations and procedures that affect remote sites and communication links, and advise on station status (e. g., when station is out, advises as to what specifically is wrong, what is being done to correct situation, and estimate of when it will be back in action).

Since a significant portion of his job is implementing operational and procedural changes and providing advice on outages or status of GOSS network which require changes in operations and procedures, he will normally report to the Operations and Procedure Officer some time prior to and during either a simulated or actual mission operation.

Vehicle Systems Officer (VSO): The VSO will have overall responsibility for the status of all systems for both vehicles and will report directly to the Flight Director. He will advise the FD on any system when it exceeds tolerances and limits or when predictions based on trend analyses, indicate that tolerances and limits probably will be exceeded. He will also make recommendations to the FD as to corrective or remedial actions to be taken. For example, he would advise the FD on the relative capability remaining for the two vehicles, so the FD could decide which of the possible maneuvers would be optimal in terms of fuel utilization, oxygen utilization, etc.

The VSO will have at least two advisers, one for the Gemini vehicle and one for the Agena. The tasks involved in the functions of monitoring and advising on vehicle systems, can be organized either by system, across vehicles or by vehicle, across systems. Although the systems functionally may be identical or nearly identical for both vehicles, the detailed design of the systems will vary and, therefore, the knowledge required for understanding a specific system may also vary considerably for the two vehicles. If one person is dealing with functionally similar systems requiring different knowledges, there is an increased likelihood that either errors or time delays could result when a stressful situation arises. It is for this reason that the overall systems monitoring has been divided by vehicle rather than by functionally similar systems.

When information requirements for displays are detailed, it may be necessary to increase the number of advisors, if the workload becomes excessive.

Vehicle Systems Status Advisor (Gemini): The Vehicle System Status Advisor (Gemini) will monitor the functioning of the vehicle systems to detect dangerous or impending dangerous, out of tolerance, and out-of-limits conditions in the vehicle and assist the VSO in making recommendations as to corrective and remedial actions. He will monitor information related to the following:

- a. Sequencing data (e. g., information concerning clocks started, system events such as separation, chute deployed, paraglider deployed).
- b. System guidance (e. g., information concerning the vertical platform, along-track and across-track platforms, air speed, angle of attack).
- c. Propulsion and stabilization (such as OAMS fuel quantity, OAMS oxidizer quantity, helium pressure, OAMS thruster temperature, pitch, roll and yaw).
- d. Instrumentation and communication (such as 5 V reference and uplink "Telemetry calibrate" command).
- e. Structures (such as physical separation between booster and spacecraft).
- f. Power (such as main and secondary bus voltage and current, H<sub>2</sub> quantity and pressure).

In the event a contingency or an impending contingency results from degrading performance of one of the vehicle systems, this advisor will interpret telemetered or voice-reported information for the VSO. (The VSO will, when necessary, consider this in relation to information on the other vehicle and advise the FD and the Flight Dynamics Officer, if the information affects the performance of his tasks.)

Vehicle Systems Status Advisor (Agena): The Vehicle Systems Status Advisor (Agena) will have duties similar to the advisor for Gemini. He will monitor information related to the following:

- a. Command and communication (such as time code, gyro commands, flashing light, verifications).
- b. Guidance (such as pitch, roll, yaw, control gas, etc.).
- c. Propulsion (such as start tank pressure, oxidizer and fuel temperature and pressure).
- d. Structure (such as booster and nose cone separation, horizon sensor fairing temperature).
- e. Power (such as 28 V supply voltage and DC battery bus).

Vehicle Communicator: The Vehicle Communicator provides a similar function to that of the CAPCOM in Mercury. The Vehicle Communicator will be acting as a ground-based copilot and, therefore, will have had the same training as the actual vehicle crew. He will have primary responsibility for voice information exchanges between the spacecraft and the ground. Once the voice links have been established, the Vehicle Communicator will manage all programmed information exchanges with the spacecraft crew over the voice channel and will present to the crew responses to requests by the crew during the flight. The Vehicle Communicator also has responsibility for recording the status of all major events that are occurring during the mission. (All test objectives status and their accomplishment, and changes in priority of accomplishment or omission are the mission events. Since this can be a huge task, an assistant is defined to aid the vehicle communicator.) The Vehicle Communicator's responsibilities also include the assessment of the astronauts' capability to perform the test objectives. In performing this responsibility, he has the Biomedical and Environment Monitor

(Flight Surgeon) to assist him. He informs the FD of such assessments so that the FD can decide the direct changes in the operations and procedures of the mission.

Flight Test Assistant: The Flight Test Assistant will help to account for the accomplishment of objectives, changes in priority or omissions, and to coordinate the changes or modifications to test objectives with personnel outside the MOCR (e. g., on prolonged missions, the accomplishment of test objectives and analyses of results may dictate new objectives such as asking the crew to take more or different observations and/or actions). This assistant will help to schedule the new objective. The Vehicle Communicator will assess the capability of the crew to perform this new objective and will make his recommendations to the FD.

Biomedical and Environment Monitor (Flight Surgeon): The Biomedical and Environment Monitor will have two basic responsibilities. First, he will be responsible for determining and assessing the crew's well being. In carrying out this responsibility, he will monitor biomedical information and listen to the crew. He will inform the Vehicle Communicator of the status of the crew, assist in interrogating the crew to determine their status, and make recommendations to the Vehicle Communicator as to possible corrective action. Since environmental data is closely correlated with biomedical data, and both must be interpreted to arrive at the assessment of crew's well being and possible courses of remedial action, the environmental data will be monitored at this position. (Some of the environmental data is also needed at other positions, in particular, the Vehicle Systems Advisors. When environmental information is necessary to evaluate the performance of a vehicle system, such information will also be made available to that position.)

Flight Dynamics Officer (FDO): The FDO reports directly to the Flight Director during all GOSS operations. The FDO is responsible for planning and advising on optimum trajectories and trajectory maneuvers from launch to recovery and for abort planning during all phases

of the mission. Insofar as systems status affects planning and maintaining trajectories and trajectory maneuvers, the FDO will get inputs from the Flight Director and/or the Vehicle Systems Officers. The FDO will make recommendations to the FD regarding "commands" to the vehicles relative to maneuvers and trajectories. "Housekeeping" commands may well be delegated to remote sites. Such items as, for example, turning on transmitters and telemetry for the Agena after the station has achieved lock on, fall into this category. If not so delegated, they could be handled by the Operations and Procedures Officer and implemented through the Remote Site Coordinator.) In performing his job, the FDO is aided by two assistants; one for Titan/Gemini, the other for Atlas/Agena. The FDO uses their inputs to determine the proper actions for each to obtain the desired net result.

Detailed information requirements for the flight dynamics function may reveal that the knowledge required to perform the tasks is not great enough or different enough to justify two assistants. However, it appears that the planning activities (for the rendezvous missions) involving two vehicles with different capabilities will, on occasion, create time demands on the flight dynamics function which necessitate the use of two assistants.

Assistant FDO for Titan/Gemini: The Assistant FDO for Titan/Gemini will maintain an awareness of past history of the Titan/Gemini so that he can provide appropriate summary information to the Vehicle Systems Officer. For example, the fuel used for the last maneuver and the fuel remaining will limit the number of maneuvers possible. Using this knowledge, the Assistant FDO can rule out impossible maneuvers so that the FDO can evaluate the possible maneuvers and make appropriate recommendations to the Flight Director. The Assistant FDO is also responsible to the FDO to determine and continually up-date and maintain an optimum abort plan should failure or the desire to abort occur at any time during the mission. Should a contingency arise, the FDO will determine the appropriate recommendation or command and time of execution, and so inform the FD, who will make the final decision. The Assistant FDO is also responsible for the parameters

necessary for the recovery operations - estimated point and time of impact, the associated confidence level for these estimates, and the estimated landing points associated with abort plans. This information will be passed on to the Recovery Commander.

Assistant FDO for Atlas/Agena: This Assistant FDO fulfills an identical role to that indicated for the Assistant FDO for Titan/Gemini, except that he does not have responsibility for an abort plan, since the Agena will not necessarily be recovered.

### 6.1.2 Staff Support to MOCR

The technical staff, directly supporting the flight control personnel in the MOCR, has the responsibility to monitor subsystems or subfunctions. They perform data analysis as related to their specialties. For example, they analyze long-term performance trends to permit anticipation of contingencies and compare trends and history to derive predictions and/or evaluations. If unforeseen contingencies occur, they will have analyzed the data and could, then, relate the malfunction to performance of the malfunctioning subsystem, provide advice on the effect of this malfunction, and make recommendations as to remedial action(s) and the implications as they relate to the accomplishment of the mission. Specific groups are assigned to direct support of specialists in the MOCR.

These personnel consist of specialists in such areas as aero medical, vehicle subsystems, environment and environmental control, propulsion, etc.

The number of personnel required to fulfill these functions has not been developed sufficiently at the time of this submission, except for the support of biomedical environment and environment control. This area of support is described below.

#### 6.1.2.1 Manning Requirements for Biomedical, Environment and Environmental Control System Support Area:

In this section, the manning of the biomedical, environment, and environmental control system (ECS) support area is related to the activities performed by the personnel. The primary functions which will be performed in this area are analysis and abstraction of real-time biomedical environment and ECS data, comparison with historical data, and some manual correlation plotting of trend information. Although the ECS status monitoring is done at the Gemini System Status Adviser's console, the analytical aspect of this function is incorporated with the biomedical and environment in the support area because of the interrelationships among the three. For example, trend analysis of the total oxygen



available will have a direct bearing on the project environment at any given time and, hence, on the astronauts' physical condition.

Real-time readouts of the biomedical, environment, and ECS data will be examined by the support area personnel for differences from that data anticipated for the flight. Irregularities in the data, such as a sudden, but brief, oxygen pressure drop (possibly due to faulty telemetry) will be noted and recorded. The astronauts' verbal reports will be monitored and recorded. Also recorded will be the monitor's impression of their health and well-being as judged from their voices.

Records will be kept on trends of such items as total oxygen remaining, time remaining before oxygen is exhausted, etc. Derivation of pulse rate from EKG among other analysis, will be performed in the support area. Personnel will have the instrumentation available to compare historical data obtained during the mission with the real-time information (for example, comparing EKG during various phases of the flight). Summaries of data reduced by data processing equipment will be available in this support area.

In addition to the analytical function, these personnel will maintain files on the voice comments, health histories of the astronauts prior to the flights, and irregularities which occur in the received data.

Personnel within the support area will report to the Biomedical and Environment Monitor and to the Gemini Systems Status Advisor that information relevant to their respective areas of interest. However, these flight operators within the MOCR will have the capability to request any data they might desire from the support area. The support personnel will also have the responsibility to reduce non real-time data obtained in biomedical experiments.

A preliminary listing of the number of personnel required for the support area according to the functions performed within the area, follows:

<u>Function</u>	<u>Personnel Required</u>
a. Real-time voice, biomedical, environment, and ECS monitoring and analysis. Direct communication with MOCR flight operators.	2
b. Maintain verbal report file, health history file, irregularity file, and data summaries	1
c. Manual trend analyses and monitoring, historical data comparison	1

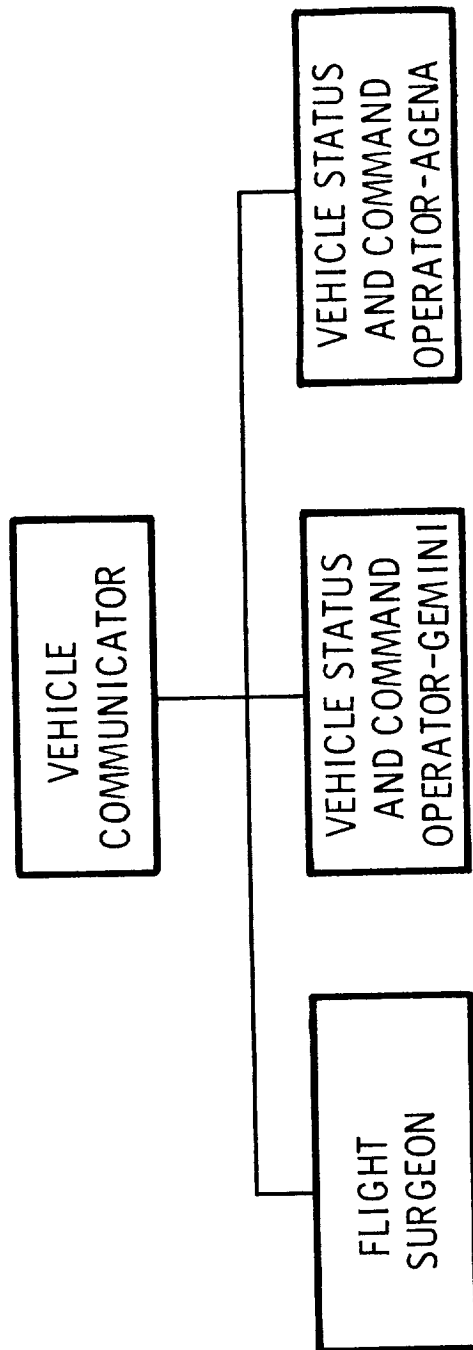
All of these personnel must have the flexibility to assist in non-real-time medical experiment data analysis.

## 6.2 REMOTE SITE NETWORK OPERATIONS

The tentative manning for the remote site flight control team is considered for both command sites and non-command sites. For the non-command sites, the team consists of a Flight Surgeon, Vehicle Communicator, and possibly a System Monitor. Duties and responsibilities of the Flight Surgeon are similar to those of the same position in the IMCC. The Vehicle Communicator's functions are the same as the Vehicle Communicator's functions in the IMCC except that he also functions as the "local" Flight Director and is in charge of the station during mission operations. He also is fully informed on all major events that are to occur during the current pass and communicates with the astronaut(s) to ascertain whether planned events occur. The System Monitor has a responsibility to maintain knowledge of current status on telemetry, and to analyze the telemetry so that he may advise the Vehicle Communicator on the status of the vehicle and the details of event occurrence. (After information flow is analyzed and the processing of telemetry and transmission to the IMCC for the Gemini missions is defined, it is likely that this position can be eliminated and that the Vehicle Communicator can assume the duties of the System Monitor.)

For command sites, the team structure is somewhat different (see Figure 6.2-1). Assuming that the electronic design of the command systems for Gemini and Agena are different (possible but not desirable), the procedures and understanding of the two may be quite different. It may be necessary, then, to have separate individuals monitor the status and communicate with the vehicles to prevent conflict of actions or errors in operation. The Vehicle Status and Command Operators have the responsibility to monitor telemetry and issue recommendations or commands at the direction of the Vehicle Communicator, if such authority has been delegated to him.

6.2-2



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### 6.3 LAUNCH CONTROL OPERATIONS

This report assumes that all functions currently administered during countdown at the Mercury Control Center will be transferred to the IMCC at the Manned Spacecraft Center in addition to all additional functions required by the more sophisticated operation.

The organization for launch operations for Gemini rendezvous missions is shown in Figure 6.3-1.

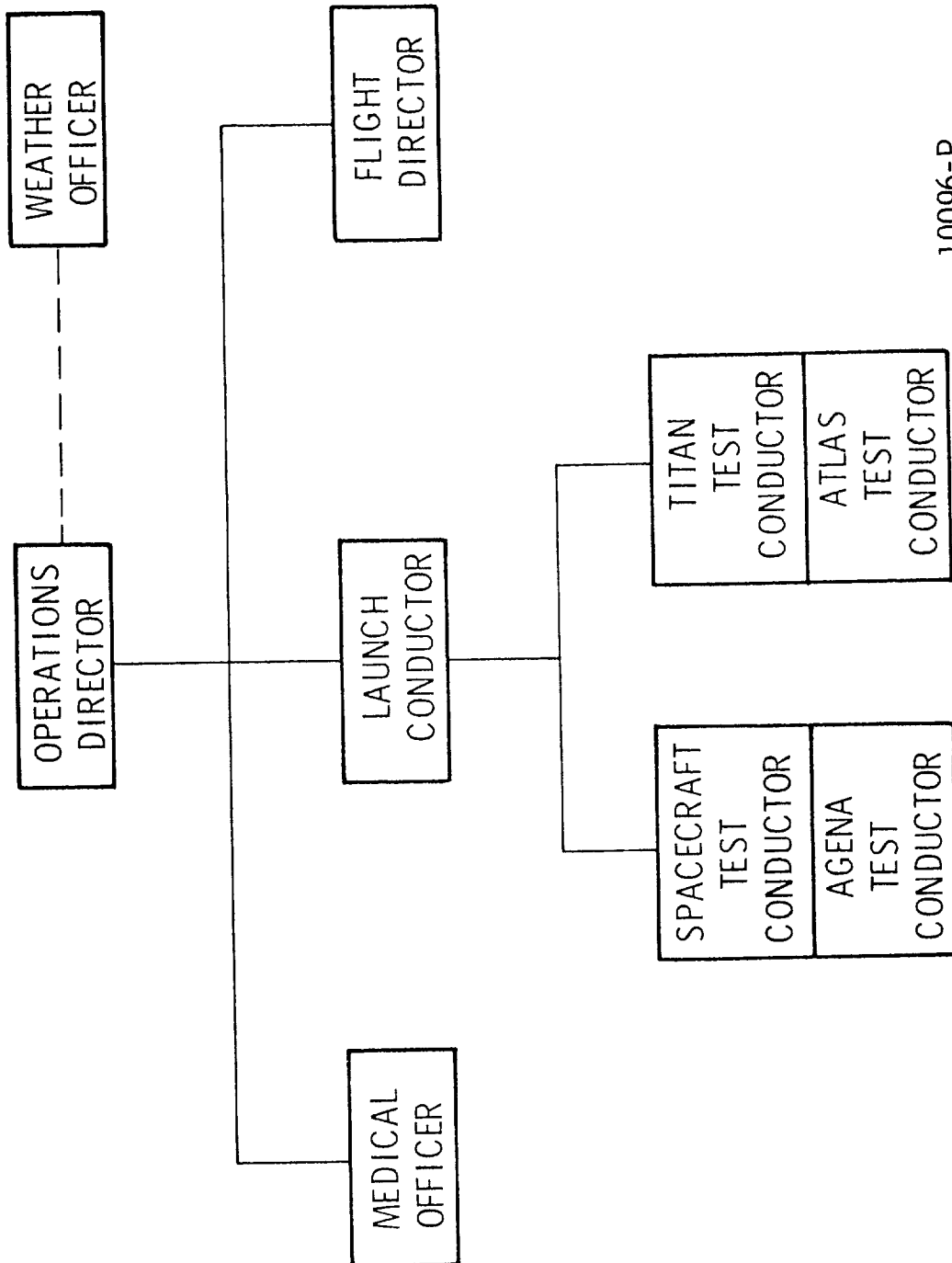
This organization consists of personnel at the launch area and at IMCC. The personnel in the launch area who report directly to the Operations Director at IMCC are the Medical Officer and the Launch Conductor, supported by test conductors for boosters and vehicles.

Launch Operations Director. The Operations Director has the overall responsibility for launch operations and determines whether to launch, delay, or cancel the operation, consistent with his delegation of authority from the Flight Director at the IMCC.

Medical Officer. The senior medical officer has the responsibility to determine if the vehicle astronauts are in a "go" condition for the mission. He reports on their status to the Operations Director and makes recommendations as to holds, changes in personnel, or scrubbing the operation.

Launch Conductor. The launch conductor has overall responsibility to determine the state of readiness of the boosters and vehicles, and to conduct the pre-count and countdown operations. He advises the Operations Director as to the status of these activities and makes recommendations as to delaying or continuing the operation. The responsibility of each Booster and Vehicle Test Conductor is analogous. They all report to the Launch Conductor.

Flight Director (LCC). The Flight Director (LCC) has the responsibility to determine the readiness of GOSS (remote site, communication networks, IMCC, computational angles, etc.) for the operation and make recommendations to the Launch Operations Director to hold, delay, or continue launch operations.



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Figure 6.3.1 Tentative Organization for Launch Operations

Weather Officer. The Weather Officer reports on all aspects of weather that may influence launch or any of the mission phases and recommends the appropriate course of action to the Operations Director.

Range Safety Officer. The Range Safety Officer works closely with the Operations Director and is responsible for safeguarding personnel and property in the surrounding areas. He initiates cutoff and/or destruct of the booster when range safety limits are exceeded.

## 6.4 RECOVERY CONTROL OPERATIONS

Recovery control operations are normally directed from the IMCC at MSC, except if delegated during launch and early powered phase to the launch area. The Recovery Commander will be located within the IMCC but not necessarily in the MOCR. The Recovery Commander has various recovery forces at his disposal which are dispersed according to abort plans provided by the Flight Director.

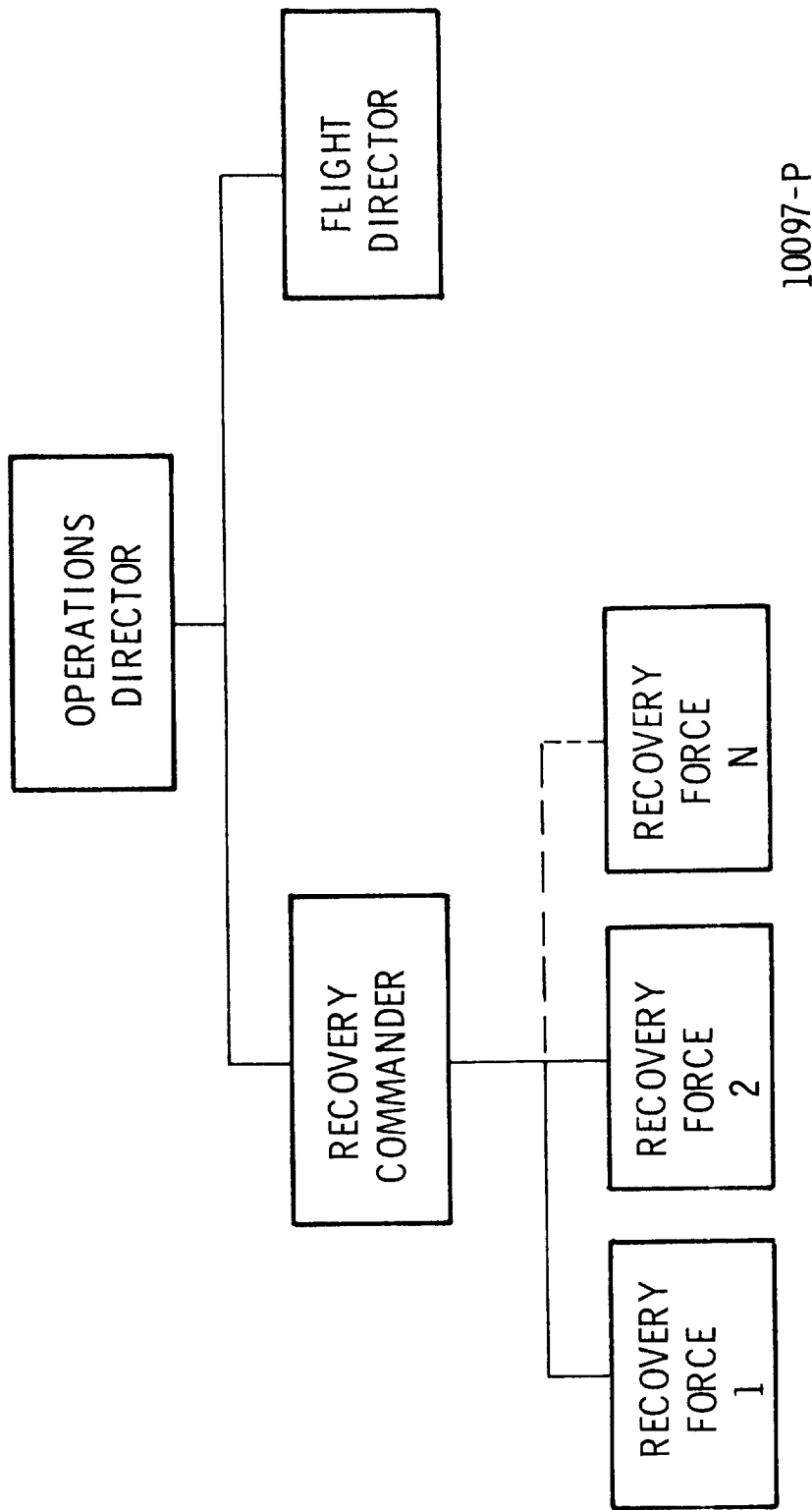
The organization for recovery operations is shown in Figure 6.4-1. A summary of these positions is described below.

Recovery Operations Director. The Recovery Operations Director has overall responsibility for recovery operations and informs the Recovery Commander of plans and/or impending recovery including the necessary information to initiate such activities.

Recovery Commander. The Recovery Commander has the responsibility to implement the recovery operation including the planned deployment of recovery forces and the directing of recovery forces on the basis of estimated point and time of landing.

Flight Director. The Flight Director has the responsibility of providing estimated point and time of landing, the associated confidence level for these estimates, and the estimated landing points associated with specific abort plans.





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Figure 6.4-1 Tentative Organization for Recovery Operations

## 6.5 NUMBER OF PERSONNEL AND DUTY CYCLES

The number of personnel required for an extended operation (two weeks, for example) that is run on a 24-hour basis depends on several factors. First, the number of hours one may work in a week will determine the number of crews. For example, if no overtime is permitted, thereby restricting any one person to a 40-hour week, the number of crews required for such around-the-clock operations is 4.2. (This factor would have to be multiplied by some percentage, 5-10% to account for sickness accidents, emergency leaves, changes in personnel, etc.) Second, work-rest cycles for the tasks also influence the number of personnel. For example, evidence from vigilance studies, involving the performance of relatively passive tasks requiring little action and consisting primarily of monitoring to determine non-normal conditions, indicate that duty cycles should range from 2-4 hours to diminish decrement in performance. An overlying factor is personal adjustment to varying work cycles. Studies have tended to show that well-motivated personnel can work 4 hours, rest two hours, for as long as 15 days without showing a decrement in performance. On the other hand, some individuals take as long as two to three months to adjust, physiologically as well as psychologically to changes from their normal work-rest cycle.

Literature is being reviewed as to the work-rest cycles and performance, to permit recommendation of a work-rest cycle so that a determination of the number of personnel required for operations, can be made. However, a limiting factor is the number of hours a person can work in one week. A policy statement defining this limit should be established by NASA before the number of personnel required for operations can be estimated.

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